**Introduction**

The protective link is an oil immersed, expulsion type fuse designed for use in the high voltage circuit of a distribution transformer. Westinghouse originally developed the protective link as part of the CSP system of distribution transformer protection. When used in the CSP scheme, the function of the protective link is to disconnect a defective transformer from the feeder circuit and to limit the severity of the damage to the transformer in case of an internal fault. The protective link is a simple device. It consists of a fuse wire element (copper or copper alloy) contained within an insulating tube. The wire is welded to a top electrode at one end and crimped to a bottom electrode or welded directly to the cable lead at the other end.

Protective links are available in a variety of fuse sizes and voltage classes. In most applications today, the protective link is used in series with a partial range or back-up current limiting fuse. The current limiting fuse is typically mounted inside of the transformer when the transformer is the pad mounted or submersible type and mounted externally when the transformer is the overhead type. The series combination of protective link and back-up type current limiting fuse adds an additional layer of fuse coordination that must be performed for proper functioning of both devices.

**Fault interruption**

The fuse element contained in the insulating tube melts in response to the heating caused by the flow of fault current through the fuse wire. After the wire melts, an arc is established inside of the fuse tube. The heat of the arc burns back the fuse wire element and the arc length increases.

The arc length determines the resistance that the opening protective link inserts into the circuit. Since the arc is relatively short, the arc resistance is low and the arc voltage across the opening element is small compared to the 60-hertz system voltage. The protective link (and most expulsion type fuses) cannot develop enough arc voltage to drive the fault current to zero. The arc can only be extinguished when the fault current passes through a natural current zero. As the fault current passes through zero, the arc is momentarily extinguished and its ionized gas cloud is then pushed out of the fuse tube (hence the term "expulsion fuse"). If the voltage withstand of this un-ionized gap is strong enough to withstand the transient recovery voltage that develops as the current passes through zero, the arc will be extinguished and the fault will be cleared.
**Ratings**

Protective links are available in three voltage classes - 15 kV, 23 kV and 34.5 kV. Interruption rating is defined by the voltage across the protective link during and after fault interruption. The interruption rating greatly depends on the transformer tank’s ability to withstand the energy released during fault interruption. The ratings were determined for cylindrical distribution transformer tanks of the vented cover design. Ratings in rectangular pad mounted transformer tanks will be equal to, or greater than the stated values due to the rectangular tank’s greater ability to withstand the energy released during fault interruption. See Table 1 for ratings details.

**Table 1**

<table>
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<tr>
<th>Application voltage</th>
<th>Interrupting rating (rms symmetrical amperes)</th>
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<tr>
<td>2400 V</td>
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<td>4800 V</td>
<td>4800</td>
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<td>3500</td>
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<td>3000</td>
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<td>2500</td>
</tr>
<tr>
<td>23000 V</td>
<td>1200</td>
</tr>
<tr>
<td>34500 V</td>
<td>1200</td>
</tr>
</tbody>
</table>

1 Application voltage is single phase line to ground and/or three phase line to line

**Minimum fuse curve selection**

In general, select the smallest fuse that will meet the transformer’s protection requirements. In the case of the CSP scheme, the smallest protective link is determined by the CSP breaker coordination. In all cases, the protective link has to be large enough to prevent nuisance fuse operations due to transients caused by transformer inrush currents or cold load pick-up. Fuse curve checkpoints are well established to guide in proper selection. Four TCC curve points should be checked. The protective link minimum melt curve must lie to the right of these points.

Point 1: 25 x rated transformer current at 0.01 s (transformer inrush)
Point 2: 12 x rated transformer current at 0.1 s (transformer inrush)
Point 3: 6 x rated transformer current at 1.0 s (cold load pick-up)
Point 4: 3 x rated transformer current at 10 s (cold load pick-up)

**Fuse Curve Selection for CSP Transformers**

When designing a CSP protection scheme, select the secondary CSP circuit breaker first in accordance with the protection required for the transformer. After selecting the secondary circuit breaker, select the protective link so that proper coordination between the primary side protective link and the secondary side circuit breaker is achieved. The simplest way to determine if proper coordination has been achieved is to compare the time versus current characteristics curves (TCC curves) of both devices (adjusting for the turns ratio of the transformer). Coordination is acceptable when, for all values of secondary fault current, the circuit breaker will clear the fault before the protective link melts.

**Time current characterestic (TCC) curves**

Two curves describe the time versus current characteristic of the protective link. Curve number 1ZUA567001-AAA represents the minimum melt curve (note that this supersedes curve number 735701). Curve number 1ZUA567001-AAB is the total clearing curve (note that this supersedes curve number 697700). These curves were created in accordance with the requirements of IEEE standard C37.47.
Coordination with current limiting fuses

The nature of most expulsion fuses is their inability to drive the fault current to zero before a natural current zero occurs. These fuses will always allow at least one full loop of fault current before circuit interruption. Because of their interruption characteristics, expulsion fuses have very limited fault interruption capability. Today, most protective links are used in series with a back-up or partial range current limiting fuse so that the series combination of both devices provides interruption capability across the full range of available fault currents. When applying the protective link in series with the partial range current limiting fuse, additional coordination issues must be addressed. It is the nature of the partial range current limiting fuse that it cannot interrupt low fault currents and has, in fact, a minimum interruption rating. The function of the expulsion fuse in this series application is to interrupt the low fault currents and clear the fault before the fuse elements within the current limiting fuse melt, in a sense protecting the partial range current limiting fuse.

The coordination between the protective link and the current limiting fuse is a critical element in these series combination protection schemes. The current limiting fuse manufacturer must be consulted to obtain the requirements for proper coordination between the two fuses.

Protective link TCC curves

In order to facilitate the coordination of the ABB protective link with partial range current limiting fuses, ABB has retested and created a new set of protective link time current characteristic (TCC) curves. These curves are:

- Curve 1ZUA567001-AAA which is the minimum melt TCC curve according to IEEE standard C37.41-2000, Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches Fuse Disconnecting Switches, and Accessories
- Curve 1ZUA567001-AAB which is the maximum clearing TCC curve according to the same standard.

Note that the previously issued curves 697700 and 735701 can continue to be used for coordination with CSP circuit breakers, if desired. ABB recommends that the newly issued curves be used when coordinating with up stream current limiting fuses.

Traditional TCC Curve Overlay Coordination

Coordination exists if the total clearing TCC curve of the protective link crosses (with appropriate margin) the minimum melting TCC of the partial range current limiting fuse at a current equal to or greater than the current limiting fuse rated minimum interrupting current. To protect the expulsion fuse from attempting to interrupt at a current higher than its rated maximum interrupting current, the crossing of the two curves should also occur at a current below the protective link maximum interruption current rating.

Matched Melt Coordination

In certain series combination protection schemes not only must the protective link be coordinated with the current limiting fuse using traditional TCC curve overlay methods, but additional coordination techniques must also be applied to make sure that the protective link melts open under any fault condition that causes the current limiting fuse to melt and operate. This special case occurs most typically in wind farm transformer applications where the system voltage is 34 kV, delta and the voltage rating of the partial range current limiting fuse is 23 kV. In this particular situation, not only must the standard curve overlay coordination technique be used but an additional coordination technique called matched melt coordination must also be used to ensure that the protective link always opens under any fault condition.

! Warning
Always consult with the current limiting fuse manufacturer to determine the exact coordination requirements for their device.
Matched melt coordination requires that the protective link maximum melt \( I_t \) be less than or equal to two times the current limiting fuse minimum melt \( I_t \).

\[
\left[ I_{Mn}^2 \right]_{PL} \leq 2 \left[ I_{mn}^2 \right]_{CLF}
\]

Where

- \( I_{Mn}^2 \) = maximum melt \( I_t \) for the protective link
- \( I_{mn}^2 \) = minimum melt \( I_t \) for the current limiting fuse

See table 2 for maximum melt \( I_t \) values for the protective links.

### Table 2 - Maximum melt \( I_t \)

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<th>Protective link curve number</th>
<th>Maximum melt ( I_t ) (A²s)</th>
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<td>3</td>
<td>300</td>
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<td>3A</td>
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<tr>
<td>4</td>
<td>900</td>
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<td>5</td>
<td>( 1.50 \times 10^3 )</td>
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<td>5A</td>
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<td>7</td>
<td>( 10.5 \times 10^3 )</td>
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<tr>
<td>7A</td>
<td>( 18.5 \times 10^3 )</td>
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<td>8</td>
<td>( 30.5 \times 10^3 )</td>
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<td>11</td>
<td>( 590 \times 10^3 )</td>
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</table>

### Circuit connection

The protective link is connected between the primary winding and high voltage bushing. A jack bolt (style number 240A394H01 ordered separately) fits into the 0.25 x 28 thread in the top terminal of the protective link and may be used to make up the top connection to the link. In lieu of this bolt, any standard 0.25 diameter x 28 threads per inch x 0.38 thread length bolt will work. The lower connection to the protective link is made through the flexible cable lead. The flexible cable lead is specified on the dimension sheets as: “number of wire strands” – “individual wire strand thickness” (example 259-0.005 = 259 strands of 0.005 diameter wire). Standard mounting configuration is in a near-vertical to vertical position in round tank transformers and horizontal to vertical in pad mounted units. All energized parts of the protective link must be under oil and spaced away from all other energized or grounded parts with sufficient distance to withstand all operating and test voltages. The transformer tank design must be capable of absorbing the arc energy of the protective link through tank venting or other means. The interrupting rating of this device is a function of the tank design and the live part insulation.
Mounting Accessories

Three different methods may be used to mount protective links.

The first option is to use the narrow groove flat clip (style number 75D0426H01). It is placed in the small groove around the protective link. The ends are then closed together and the mounting bolt run through the eye ends of the mounting clip into the insulating structure.

The second option is to use retaining rings and a terminal block. The retaining rings (style number 9820A65H05) fit into two small grooves on the fiber tube body and secure the fuse in the terminal block (style number 584B903H01). This mounting arrangement is shown in the figure above.

Finally, the protective link may also be mounted using an insulating block. This mounting scheme is shown on dimension sheet 44-889, page 13.

Ordering details

Protective links are ordered by style number and selected by voltage rating and curve number.

Table 3 - Protective link ordering data

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<th>Curve number</th>
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Table 4 - Data points for minimum melt curve in Amperes

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Data points are presented as a convenience. The published curve 12UA567001-AAA, Rev 2 should be used for coordination.

Table 5 - Data points for total clearing curve in Amperes

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Data points are presented as a convenience. The published curve 12UA567001-AAB, Rev 2 should be used for coordination.
For more information please contact:

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Catalog Numbers:
529B581Gxx
779C667Gxx
345B995Gxx

Plotted to Minimum Test Points
Fuses Tested in oil starting at
25°C With No Initial Load
Applicable Standard IEEE C37.47

ABB Inc,
1128 S. Cavalier Drive
Alamo, TN 38001, USA
Telephone: 731-698-5561
Fax: 731-698-5377
www.abb.com/electricalcomponents

MINIMUM MELT TIME - CURRENT CHARACTERISTICS
PROTECTIVE LINKS IN TRANSFER OIL
(FOR CLEARING CHARACTERISTICS SEE CURVE NUMBER IZUA567001-AAB

CURVE NO. IZUA567001-AAA
Catalog Numbers:
529B581Gxx
779C667Gxx
345B995Gxx

Plotted to Maximum Test Points
Fuses Tested in oil starting at 25°C With No Initial Load
Applicable Standard IEEE C37.47

TOTAL CLEARING TIME - CURRENT CHARACTERISTICS
PROTECTIVE LINKS IN TRANSFER OIL
FOR MINIMUM MELT CHARACTERISTICS SEE CURVE NUMBER IZUA567001-AAA

CURVE NO. IZUA567001-AAB
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MINIMUM MELT TIME CURVE NO. 120A567001-AAA
TOTAL CLEARING TIME CURVE NO. 120A567001-AAA

ABB Inc.

TITLE 15.0 kV PROTECTIVE LINK OUTLINE

REVISION SHEET 44-889 PAGE: 10 REVISION: 05

DIMENSIONS ARE IN INCHES.
### Table

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### Diagram

- **0.53 (13.5mm) WIDE x 0.040 (1.0mm) DEEP GROOVE**
- **0.075 (1.9mm) WIDE x 0.030 (0.8mm) DEEP GROOVE**
- **0.25-28 UNF 3B x 0.38 (9.7mm) DEEP MODIFIED THREADS**
- **0.75 (19.1mm) DIAMETER FIBER TUBE**
- **3.44 (90.2mm)**
- **0.60 (15.2mm)**
- **5.50 (139.7mm)**
- **7.00 (177.8mm)**

### Notes

- **AVERAGE CLEARING TIME CURVE No. 735701**
- **MINIMUM MELTING TIME CURVE No. 697700**
- **DIMENSIONS ARE IN INCHES.**
Suggested Mounting for 34.5 kV Protective Link
(Block is not supplied by ABB)

1: Dimension A=2.5 (63.5mm) when mounting to insulating board
   Dimension A=5.0 (127.0mm) when mounting to steel frame
2: Insert protective link into mounting hole
3: Tighten through bolts to secure protective link.
   Mount to transformer superstructure using mounting holes and suitable hardware.

Holes For Bolts To Secure To Transformer Superstructure

Drill hole before making saw cut

Saw cut, approximately 0.12 (3.0mm) wide

Through Bolt
Approximately 0.25 (6.4mm) Steel

ABB Inc.
Components & Insulation Material

MOUNTING BLOCK

DIMENSIONS ARE IN INCHES.