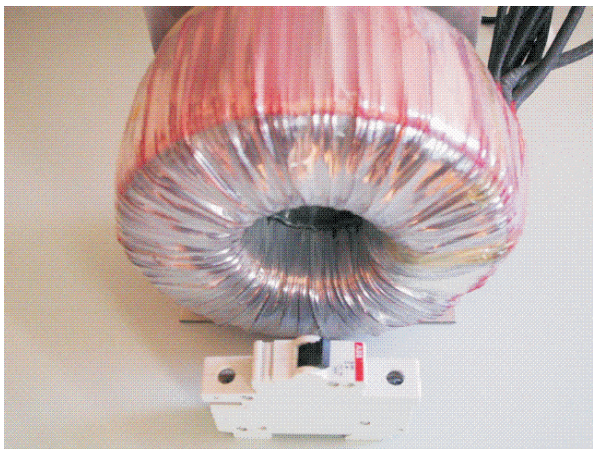
current inrush avoider for toroidal-transformers



Picture 1 shows a 1 kVA, 230 V toroidal core transformer and a C 4 A power circuit-breaker.
The toroidal core transformer has low losses and a nominal current of 4,3 Aeff, but an inrush current of 56 times of the nominal current = 240 Aeff. The C 4 A line protector switch trips when 6 times of the nominal current flows = 24 Aeff. The inrush current of the transformers is 10 times higher.
Conclusion: The toroidal core transformer and the power circuit-breaker are not combinable.

It´s a pity, that both mismatch. Each of them has advantages of it's own. The low loss transformer is energy-saving, remains cold and has a very low no-load current of only 25 mA.
The C 4A line protector switch is able to protect the transformer together with long wires behind him.
(When a short circuit occurs at the end of the long wires behind the transformer, then the short circuit currents are low and must trip the line protector switch).
In a factory area or inside of large buildings such long wires are commonly. They are supplying any actuator with 24V AC for example. Up to now big wire sizes were used for low resistance to enable the short current flowing is high enough to trip the fuse in a short time before the cable is burning.
Additionally a secondary side fusing must be spent.
But thick cables are expensive. For this reason, when a so called soft short circuit occurs, the inner resistance of the transformer should be as low as possible.

This allows again thinner wires behind the transformer.
- But this raises the inrush current, when the inner resistances of the transformer are low.

Because the sum of all resistances in the circuit between fuse and short circuit limits the short circuit current, which must trip the fuse in a short time less than 200 milliseconds.
But with a low inrush transformer it is paradox.
The copper inside of the transformer must be spent many times for the cables behind the transformer, when they are longer than 100 m and more. And the customer pays the bill.
However, when a so called „transformer-switching-relay“ is placed between the both in the picture 1, then the transformer and the line protect switch are consistent.
The transformer switching relays avoid the inrush current in all circumstances better than normally used inrush current limiters.
Sometimes so called inrush current limiters, cannot limit the inrush current in all circumstances.
They can't stand being turned on short after short circuits.
Mostly they consist of a bridged NTC or fix resistor.
After a short power line interruption they cannot limit the inrush currents, when the power line voltage comes back.
Normally used EI core control-transformers run hot even in no load state.
The reason is in the construction.
- Either a transformer has low losses or he has a low inrush current. Both together is not possible with normal costs.
With the argument for transformers with low inrush currents on correspond the argument of an easy to fuse of the transformer. That´s often published. But nobody mentions the higher warming up and the higher current losses of these kinds of low inrush transformers.

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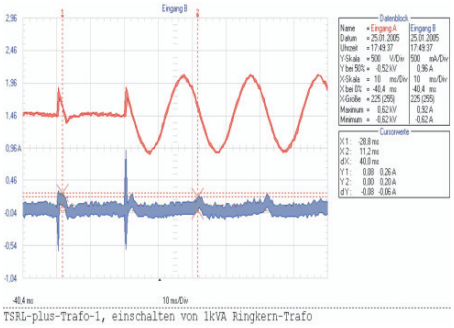
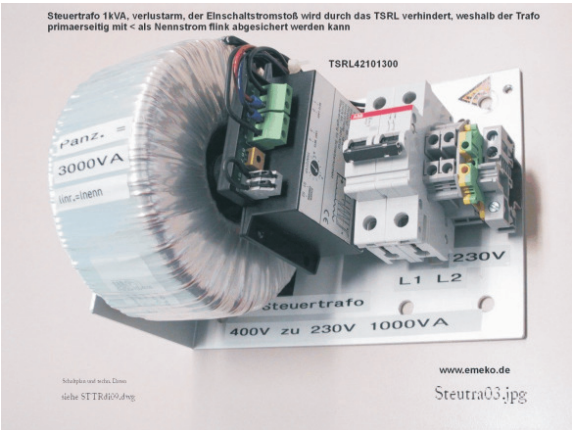
Alternatively we think it is better to use a low loss transformer together with a transformer switching relay to save energy and costs.
A so called transformer switching relay, TSR, fullfills all the needed criterions to withstand the rough industrial environment. It avoids the inrush of transformers and allows to use transformers with low losses. The fuse selection becomes very easy. The Transformer fuse can be a fast blowing type with a value of the nominal current or less.
The switching on procedure of a 1kVA Toroidal core transformer together with the TSRL is seen above. After a short time of premagnetising the transformer is fully switched on.



TSRL-plus-Trafo-1, einschalten von 1kVA Ringkern-Trafo

Picture2

The graph in picture 2 shows:
Ahead is the voltage on the transformer and above the current into the transformer.
The transformer was in no load state while switching on. Only 80 Milli-Amps are flowing.
(Softstart procedure is patented with EP 0575715)
Since more than 7 years this inrush avoiders are on the european market. They are used more and more inside of medical separation transformers or in traffic lights etc. A transformer fullfills together with a TSR the tests according to EN 61000-4-11, with fast voltage dips. No fuse is blowing when missing half a wave of the feeding voltage.
A TSR can switch on and off over 5 Million times in it's life, with no long pause between switching.
A TSR has together with a toroidal core transformer many advantages.
Only toroidal core transformers have such a small no load current, that it doesn't need to warm up the transformer.
These kind of transformers will be important in future as energy-saving transformers, when the only bad habit is eliminated, the high inrush current.
Also a bigger size of transformer is recommended when the losses must be decreased to a minimal value, while the loaded transformer must stay cool. The higher no load losses can be neglected, but the load losses are only ¼ when the power of the transformer is doubled. A 2kVA Transformer can also be fused to 0,5kVA when the load is not bigger.
In the right picture 4, a block schematic is showed. With the measuring curves of the switch on procedure and so on.
The bottom picture 3 shows a low loss control transformer with 1kVA, 400V to 230V, together with a TSRL and the 2A B power circuit-breaker on a top hat rail.



Picture 3.

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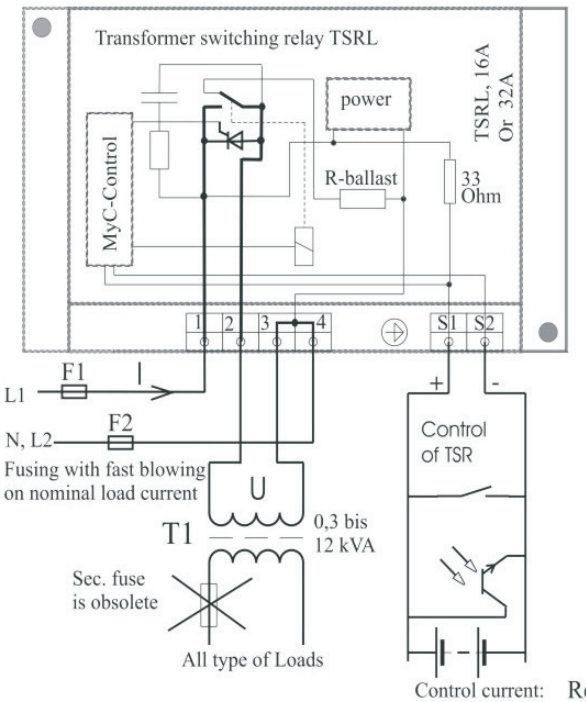
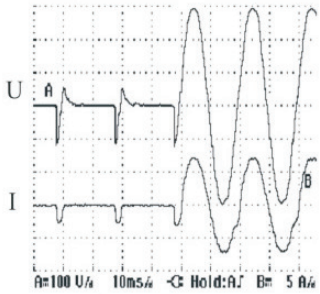
current inrush avoider for toroidal-transformers

Transformer switch on without inrush current peaks

Inrush current avoiding with a TSR
Transformer switching relay
Switch full on after premagnetising
of the transformer



Switched on with load with a TSRL



I peak = Inom = 7A peak
= current of nominal load

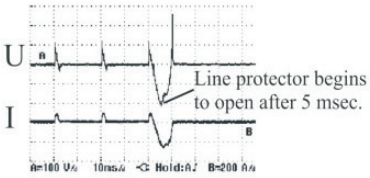
Switch on in no load state

U

I

I max. = I no load
(visible is a typically no load current)

Switch on with short circuit after transfo

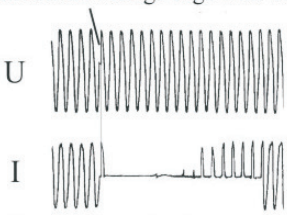


A 16A B-typ line protector
trips directly after switch on.
No damage of TSRL until 400A
for 10msec.

Advantages with a TSR:

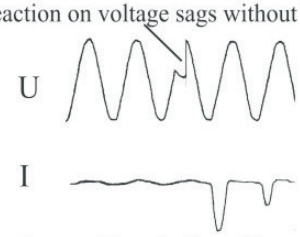
No limit in repetition of switching, no waiting time.
Fast blowing fuses with nominal current value useful.
No overheating of transformer
No damage when short circuit by correct fusing
Avoid inrushes after voltage sags and dips.
Allows transformers with low losses and max. Induction .
Replace contactor and inrush current limitor and saves monney
in cases when transformer must be switched often.

Reaction on voltage sags with TSR



I max. = Inominal
also available with fast switch on.

Reaction on voltage sags without TSR



Imax. = U peak div. with
(R line + R copper prim.)
= 200 A peak,
each fuse is blowing then

US_tsr02-e.cdr
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Picture 4.

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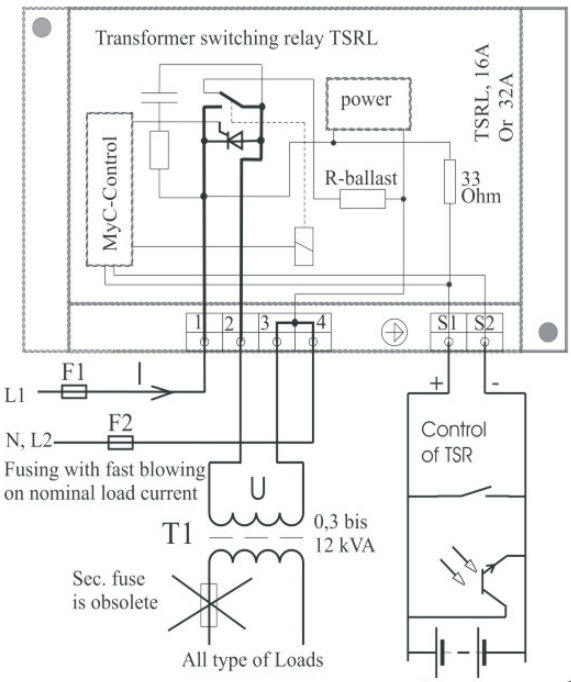
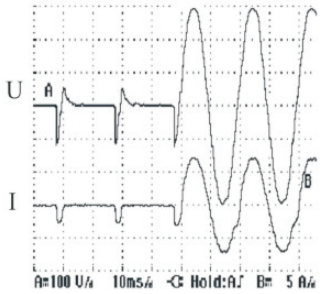
current inrush avoider for toroidal-transformers

Transformer switch on without inrush current peaks

Inrush current avoiding with a TSR
Transformer switching relay
Switch full on after premagnetising
of the transformer



Switched on with load with a TSRL



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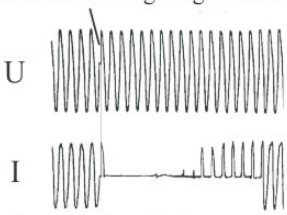
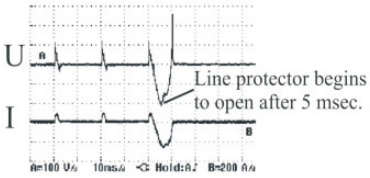
Reaction on voltage sags with TSR



I max. = Inominal
also available with fast switch on.

Switch on with short circuit after transfo



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No damage of TSRL until 400A
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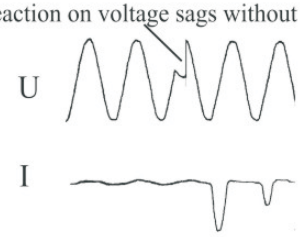
Reaction on voltage sags without TSR



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US_tsr02-e.cdr
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Picture 4.

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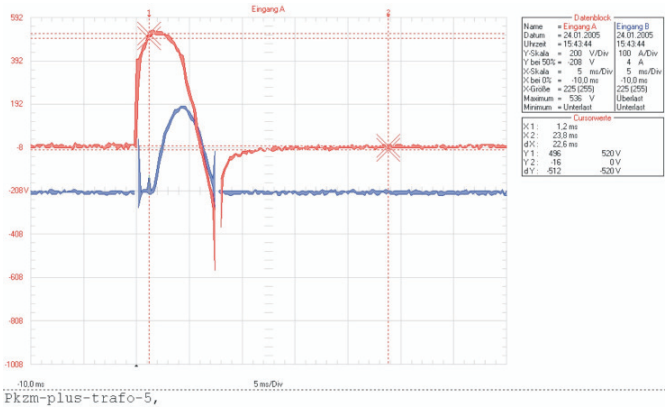
current inrush avoider for toroidal-transformers

How it runs switching on without a TSRL?

The graph in the bottom shows the switch on Voltage and current, when a 1kVA toroidal core transformer is switched on by a electro-mechanical contactor. He is fused with a PKZM0-4-T line breaker especially for transformers.

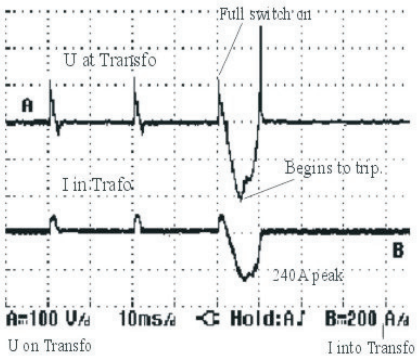


Picture 5.
(Switch on directly.)
Input A, top= Voltage at the transformer, Input B, bottom = current into the transformer.

The line protector trips within 10 Milliseconds.
The low loss Transformer has an air gap-less Iron core. He produce a inrush current of 200A peak, thats 140Aeff. (Thats the 56 times of nominal current.)
Line protector switches who have a short circuit breaker current of more than 22 times of the nominal current are not available. They´d not be able to protect the wires when a so called soft short circuit occurs.

TSRL switch on to a short circuit at his output

Fused with a 16A B-Type circuit breaker.
He trips after full switch on.
(A R-Type-10A circuit breaker would trip while premagnetising.) TSRL withstands this short circuit.



Picture 6.
When between circuit breaker and 1kVA transformer a TSRL is placed:

Channel A shows the voltage on the transformer, channel B shows the Amps into the transformer. The circuit breaker start to trip in the peak of the current after 5 msec. Only 240Amps peak are flowing. The TSRL withstands 1000Amps peak for 10 msec.
Switch on onto short circuits is no problem for the TSRL.

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current inrush avoider for toroidal-transformers

When the TSR switches on to a short circuit after the transformer he gets no damage, when the fusing is correct.

Other inrush current limiters failed this test.

Additionally: A TSRL with the option for fast recognition of so called fast voltage dips can avoid inrushes and fuse tripping when tested the equipment with EN 61000-4-11. This TSRL has also a switch off threshold from 170Veff and a switch on threshold from 185Veff.
When voltage sags occurs, no jitter with mechanical contactors is induced when a TSRL is in front of a control transformer.
A separately voltage Supervisor relay is no more needed than.

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