Folie 1 vorgetragen wird nur der Text unter den Bildern.

Avoiding of transformer inrush-current peaks with a TSR,

instead use of low inrush transformers or handling with oversized fuses or inrush-limiting with resistors.

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Manufacturer: www.fsm-elektronik.de
of TSR

(TSR = **T**ransformer **S**witch **R**elay)

Last update: 30.04.2004

1

Inrush currents of Transformers are an unsolved problem so far.

Particularly for the more and more used toroidal transformers, the inrush problem elimination is of common interest.

Many compromises and different inrush current limiters are made in past to solve the complications due to INRUSH CURRENTS.

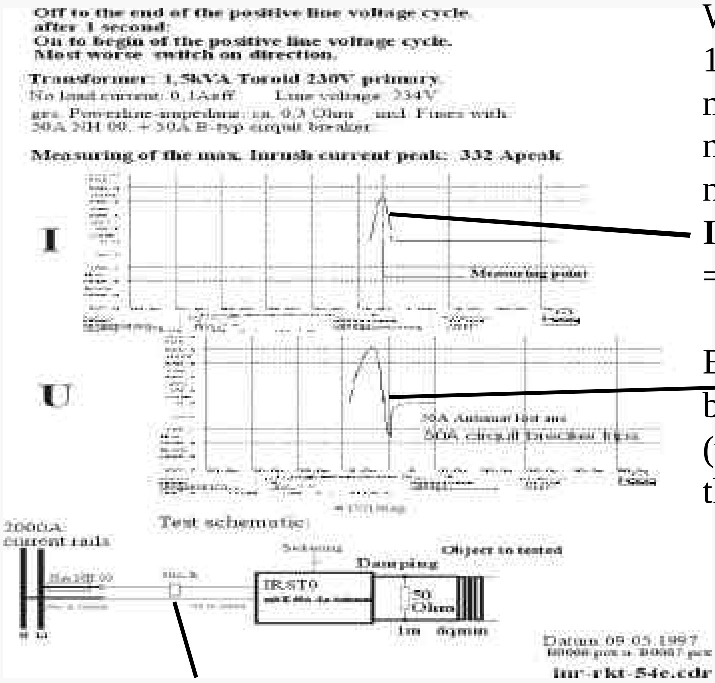
When a new technique can avoid this unwanted phenomena, then many things are more easy around construction and use of transformers.

A TSR not only limits he can avoid inrush current peaks.

TSR is an abbreviation of **T**ransformer **S**witching **R**elay

Folie 2

Typical Inrush current peak of a 1,5 kVA Toroid Transformer, fused with a 50A B-type circuit breaker.



50A B-type cirqut breaker

Worst case with a 1,5 kVA Toroid transfor-. mer at 230V, no load current = 0,1 Aeff nom. Current = 9,2 Apeak, **Inrush current = 332 Apeak**. = 36 times nominal current.

Even a 50A B-type circuit-breaker trips, (while opening it slightly limits the current rise.)

„Irst0“ was constructed with a momentanous switching 125A solid state relay and a microprocessor control.

Emeko Ing. Büro 2

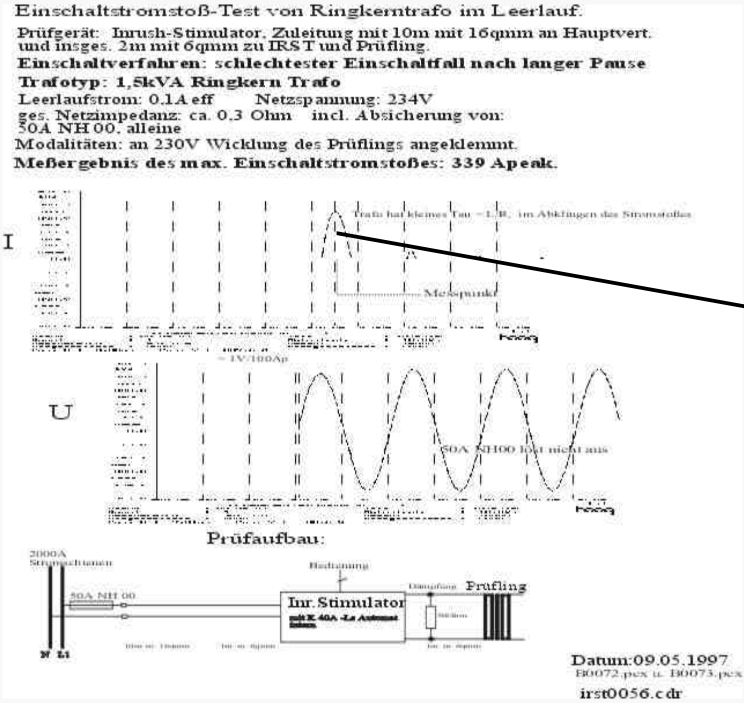
Worst case switch on, brings a maximum Inrush current peak of 36 times of nominal current.

The transformer was treated to his max. Inrush current peak. By switch off to the end of the positive half wave of line voltage, and switch on to begin of the positive half wave of the line voltage.

The remanence is in positive max. point. The iron of the transformer core can not be changed from the line voltage, in magnitude and polarity.

A 50Amps B-Type circuit breaker trips.

Measured inrush of a 1,5 kVA toroid transformer, only fused with a 50A NH00.



No load Current = 0,1 Aeff

Load current = 6,5Aeff,

Inrush = 339 a peak = 240A eff

A 50 A Fuse NH00 Type, withstands the inrush.

No circuit breaker

Emeko Ing. Büro

Folie ausblenden

3

The same picture like before, but without the 50A circuit breaker.

A 50A NH00 Fuse withstand the big current peak of 339 Amps.

But it is a big mismatch between a 50A fuse and the transformer nominal current from 6,5 A.

What is the better way?

Use a low Inrush transformer or avoid the Inrush without technical compromises?

Folie 4

burned control-Transformer

Despite output side fusing a risk remains. The better way is: Fusing at transformers rated current and avoidance of inrushes.

Such a risk really exist.

So far: High inrush current demands on fuses with high ratings. (higher than nominal current and super long time lag.)
This leads to fire hazard at over-load and particularly with **over voltage and in hot environments.**

The adequate remedial measure:
Avoidance of inrush currents with a transformer –switching relay- **TSRL, and fusing correspond application, -- if you like with nominal current and fast blowing characteristic.**

Normally Industrial control transformers has **one fuse** on the primary side with a value of 2-3 times from nominal current from input and a **second fuse** of the secondary side with 1 times nominal current from output.
When over voltage for a long time comes to the primary side, the transformer iron is going into saturation and pulls a greater non linear no-load-current from the power line. This current flows additionally to the load current and overheat the transformer.

Because of a fuse with 2-3 times from primary side nominal current, (need because of inrush,) the transformer is not protected from the fuse in this case. The secondary side fuse with nominal value do not see this over current and does not trip.

The prim. fuse is a mere short circuit protection on the input side of the transformer, not a suitable protection against so called soft-short circuits and over voltages.

Folie 5

The cause of transformer-inrush current

- In case of the iron core saturation, --which sometime happens when „switching on“ a transformer --, the copper resistance of the primary coil is **the only inrush current limiting** component together with the power line impedance in the circuit. (Line impedance is approximately 0,3 Ohm in 230V lines for 16-32 Amps.)

- The iron seems to bee absent for this short time of inrush, because the iron cannot be magnetised any further under this circumstance of saturation.

- Only the DC resistance of the coil limits the current into the transformer. The AC resistance is near zero. See measuring curves on slide 2 and 3.

There are existing many theorys of the cause of the transformer inrush. This ahead and above written theory is proven by measuring the behaviour of the transformer by voltage and current measuring with storage oscilloscopes, in case of the Switch on and no load permanent running state at different situations.

The no load current says what the iron will do, also in case of switch on.
The copper resistance of the primary coil is the only inrush current limiting component.

Folie 6

Some compromises.

- A higher copper-resistance of the primary coil reduces the inrush but it brings more losses and higher operating costs and sometimes also costs for ventilation and cooling. See next picture on slide 6.

- Reduction of the iron core saturation by means of design modifications reduces the inrush.
  These are: air gaps, lower working induction in the iron core = a bigger lamination stack, more windings, additional stray inductances, and so on. All that makes a transformer weightier, more expensive and leads to higher ohmic losses. >so this also brings disadvantages for the customer.

- Usually both is applied in order to lower the inrush peak on industrial transformers and protect it with oversized and time lag fuses.

Standard transformers must have been cheap and should have a low inrush current. This is a contradiction.
A transformer with more iron, because of low induction in the iron must be more expensive like a transformer with a higher induction in the iron.
The unwanted produced heat, because of the losses in the primary coil and iron core, must be transported outside of the cabinet with a cooling fan or heat exchanger.

In situations when the cabinet must be tight and can have no cooling equipment, because of environment circumstances, (clean room,) than a transformer must have lowest losses. And then he has a big inrush current. And then helps a TSR.

Folie 7

Behaviour of a standard control 1 kVA transformer.

Surface has more than
60 degrees C
in no load state.

The design leads to a high temperature of the transformer, (Class E40), and to a soft - Characteristic - transformer with a **big no load current amplitude**, ---due to the welded air gap in the EI-core together with a cheap iron quality –and with a higher primary coil resistance. Primary coil is the outer coil.

The Inrush is hold down by a higher primary coil copper resistance. Thinner wire diameter and longer wires, because of the primary coil is the outer coil. Stray field emission is also greater then like primary coil is inside.

The wide primary side no load current (6 A) peak in zero cross of voltage,-- is bigger than the narrow needle shaped load current peak to the rectifier capacity.

The air gap lowers the Inrush.

The air gap rises the no load current.

Higher no load current into higher ohmic primary coil brings higher losses.

This leads to the high no load temperature.

Folie 8

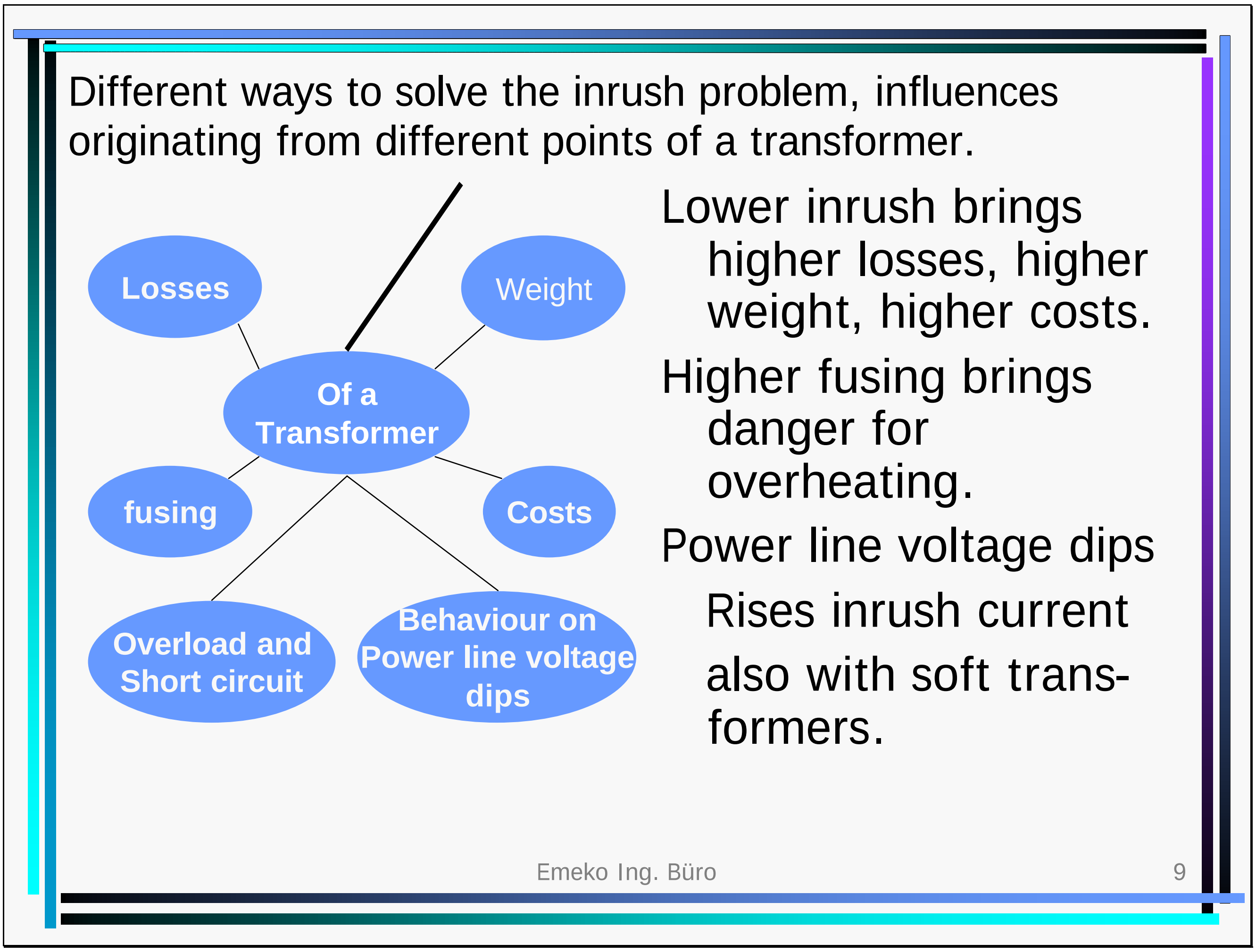
Despite increasing application of switch mode power supplies, **the conventional 50Hz Transformer remains** long time in use of many fields of electro-engineering.

- Particularly when his output voltage is direct used as AC voltage without rectifying to a DC voltage.
- Examples are: insulation-, voltage adapting- or protective low voltage transformers.

50 Hz Transformers could have 98 % efficiency and more, when they are constructed without restraints.
Toroidal transformers have a no load current to be neglected.
A 1kVA toroidal transformer has a 30mA no load current. When he is used with 50% of max. power, than he can have an efficiency of more than 98 %.

An antagonism is it, when on the one hand electronic transformers and the holy electronic around switch mode power supplies are to bread to ever higher degrees of efficiency up to 98 % and remains cool at any hundred watts.
and on the other hand, 50 Hz transformers efficiencies lower than 95 %, because of compromises, discussed above, and,
the reduction of inrush current peaks by means of design modifications, for the restraint of the fusing problem is not the least important reason for this inadequate efficiency.

Folie 9



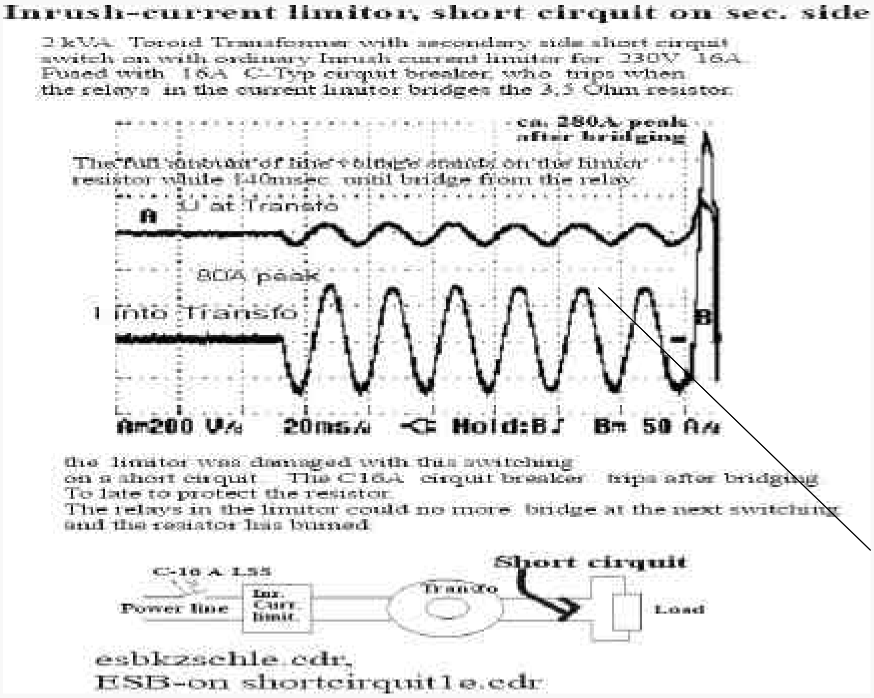
All techniques to lower the Inrush so far used has disadvantages for transformer constructor and transformer user.

Different ways to solve the inrush problem are :
Design measures on transformers.
Oversized fuses.
Limiting with resistors on the primary side while start, then bridge the resistor.
Switching on with solid state relays with random characteristic. Produces Inrushes like with a mechanical switch.
Switching on with solid state relays with peak switching characteristic. See measuring curves, only useful at transformers with a wide air gap. Very bad with Toroids see pictures 11,12 above.
Use of a Dimmer to ramp up the voltage, is expensive and not sure.
Combinations of ahead.
Limiting with NTC resistors, bridged or not bridged. See picture 13 above.

The alternative is: Short time pre magnetisation and switching on in the physically correct manner with a TSR. See Sheet 16,17.

Folie 10

Conventional inrush current limiter with transformer output shorted.



The limiter fails after first switch on.

Because of short circuit on the load it has overheated the resistor inside the limiter.

80A/1,414 *230= 13kW for 0,12 sec.
Each type of limiting resistor has a problem with a short circuit.

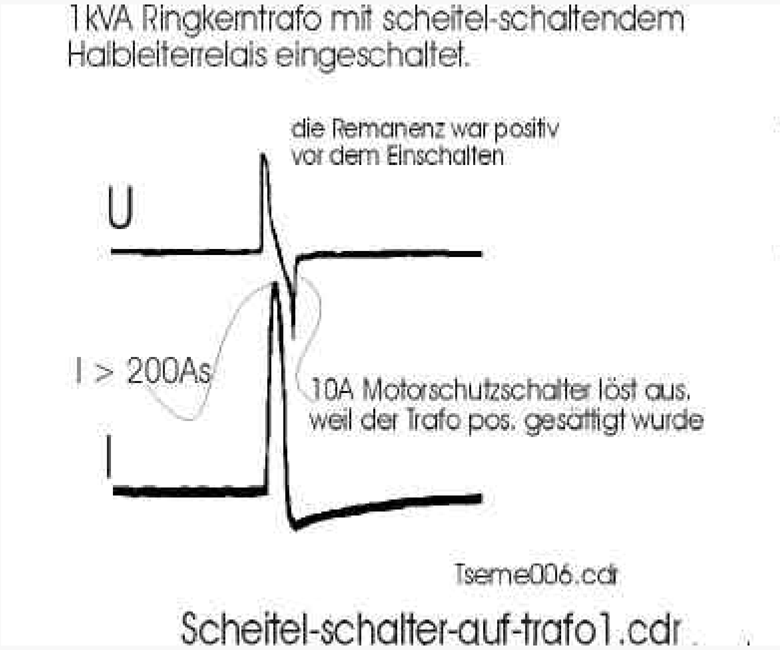
Inrush current limiters with resistors inside, need a waiting time of about 1-2 minutes to cool down after work.

After a short time of 60-200msec. after soft start, the resistor will be bridged automatically by a relay contact.

When the output of the transformer is short circuit, than the resistor inside of the limiter is overheated and will be destroyed in this short time of 60 msec.

Folie 11

switch on with a peak switch ELR, positive direction.



Not good for a 1kVA toroidal transformer with prim. 230V

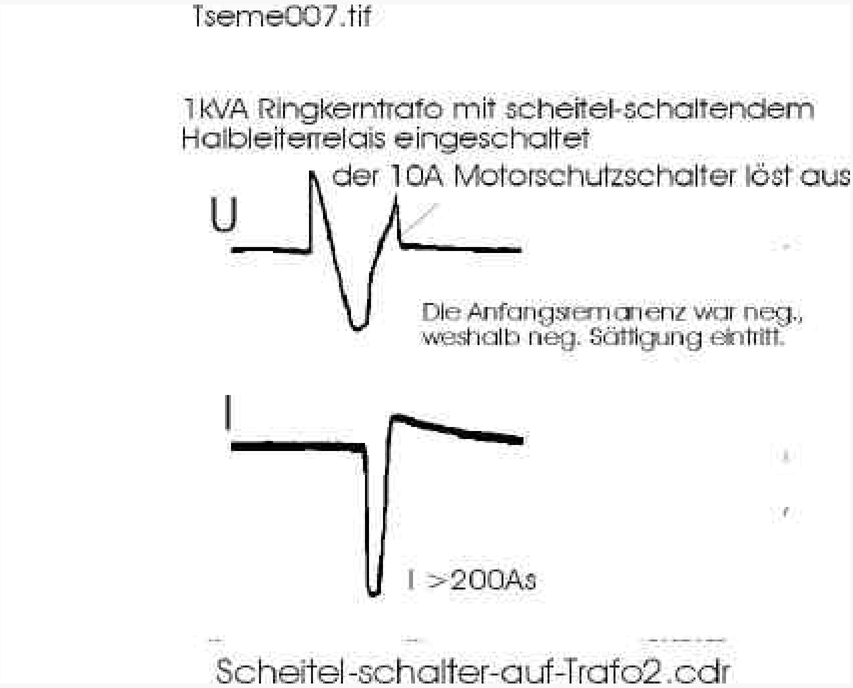
10A motor protector switch has tripped quickly

Folie ausgeblendet

Remanence was positive before switch on in the pos. Line half wave. This brings a saturation in the core.

Folie 12

switch on with a peak switch ELR, negative direction.



Not good for a 1kVA, 230V toroidal transformer

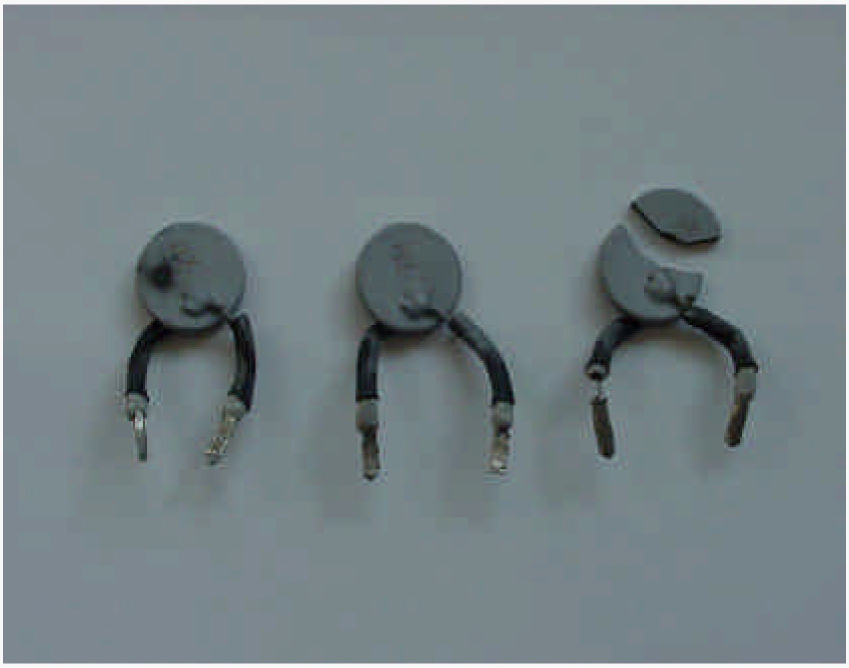
10A motor-protector switch has tripped

Folie ausgeblendet

Remanence was negative before switch on in the pos. Half wave.

Folie 13

defective NTC- Resistors.



In serie
of a 12 kVA
3 phase
Transformer
input as inrush
current limiters.
These NTC are
permanent hot
and produces
losses.
Over current peak
When Off and On
with pause of
< 1 min.
Damaged from
Over current
Peaks.

Emeko Ing. Büro *Folie ausgeblendet* 13

One has a burning hole and the others are destroyed.

Folie 14

Some people are sure that to switch on a transformer at line voltage zero crossing, with a solid state relay, is the best way to avoid inrush current peaks.

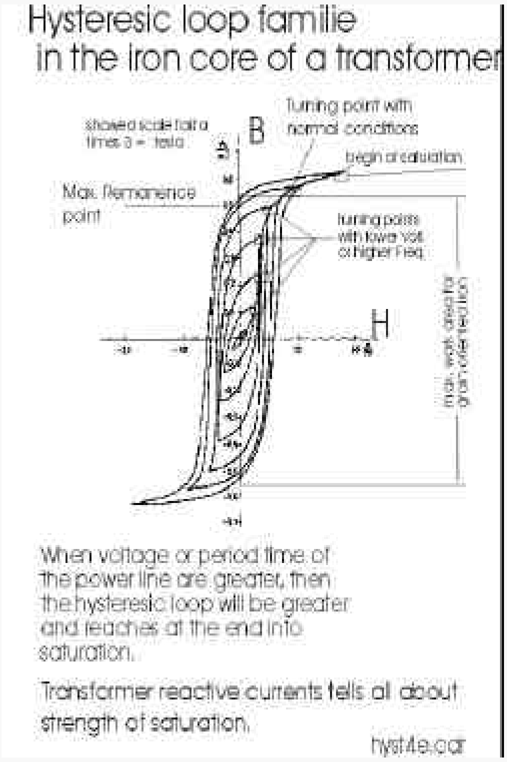
They may be lucky when accidentally they switch on at the beginning of the pos. half wave.. and..the remanence in the transformer iron was on the negative polarised maximum, because it has last been switched off at the end of the negative half wave. But they are wrong when the remanence is positive and then they have the maximum Inrush value because the iron cannot be changed in polarity from the voltage time area of the pos. Half wave, while switching on.

Folie ausgeblendet

There are many theorys to avoid inrush currents. Mostly they are wrong.

Folie 15

Hysteresic Loops in the Iron Core, and function of TSR.



During continuous operation: One half wave of line voltage, transports the magnetisation from one to the opposite turning point on the hysteresic loop!!!

With the unipolar premagnetisation-pulses of the TSR, the position of the unknown magnetisation in the core will be transported onto the hysteresic loop step for step to the best starting point for switch full on. It is the turning point, reached for continuous operation.

See picture 16.

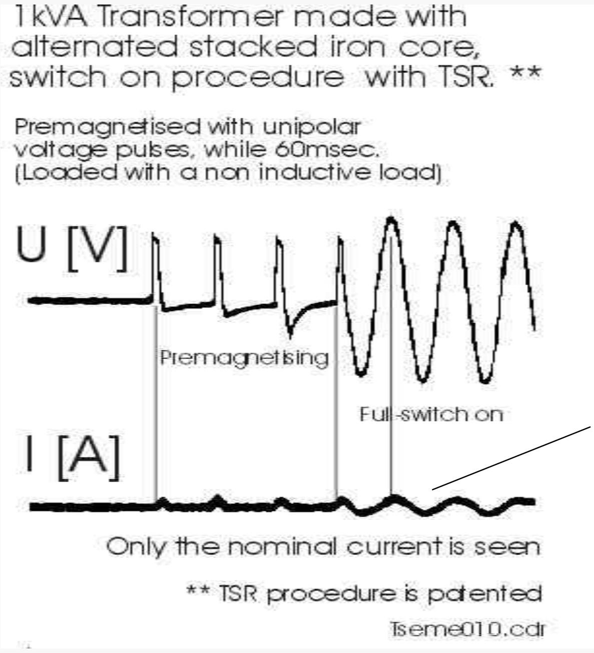
Emeko Ing. Büro 15

The magnetisation in the transformer iron core runs on a defined curve, depend of voltage amplitude and frequency of the power line. With higher frequency the curve run smaller, with lower voltage also. With lower frequency or with higher voltages the curve runs higher and goes into saturation after reaching the max. induction turning point. After switch off the transformer, the magnetisation runs to the remanence point on the B-axe with H=0, depending of the switch off point on the sinus voltage half wave of the power line..

With the unipolar pre magnetisation-pulses of the TSR procedure, the position of the magnetisation in the core will be transported onto the hysteresic loop, step for step to the turning point,
reached for continuous operation under normal conditions.
To many pre magnetisation pulses don´t matter, because they transport the magnetisation only between max. remanence point and turning point for continuous operation.
When the turning point is surely reached, after a short time, then with a counter-polarity the TSR switches full on. See picture 16.

Folie 16

Measurement curve from TSRL soft-start procedure.



The unipolar premagnetising impulses transports the magnetisation to the top right point of the hysteresic loop, see picture 15, and then the TSR switch full on in the opposite direction.

No reactive current is visible.

A relay bridges the thyristor at the beginning of steady- state operation.

No inrush current peak is visible.

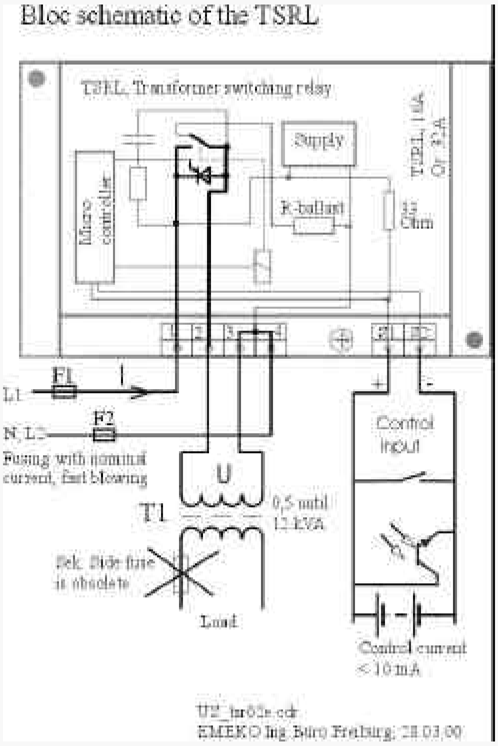
TSR procedure synchronise the transformer to the power line voltage before full switching on.

No waiting time is needed between switching.

Patented TSR procedure in the most important European countries

Folie 17

Schematic and function of TSRL.



The micro controller in the TSRL handles many options.

The TSRL is a so called hybrid relay.

Emeko Ing. Büro 17

Unique technique with thyristor and electro-mechanical relay.

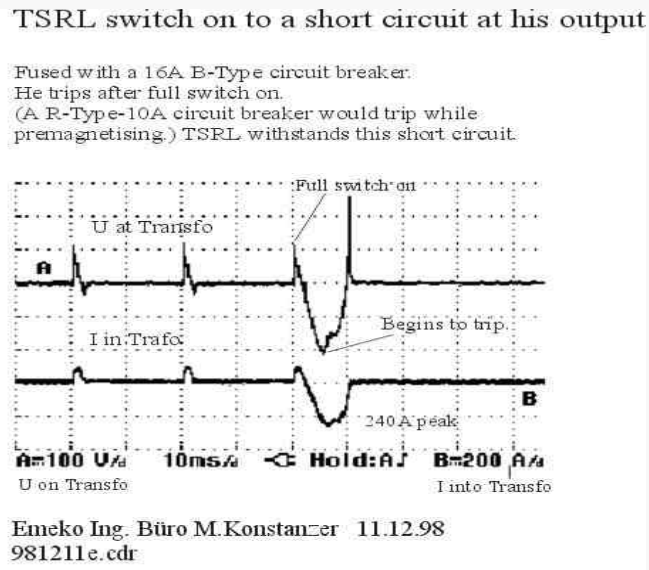
Controllable with external control contact or control voltage.

There are many different applications for the TSR procedure.

Even the TSRL are used for insulating transformers in hospitals.

Folie 18

TSRL is short circuit proof.



The line protector trips while the first full- half wave.

Short circuit is not a problem for the hybrid-relays -type of TSRL, because the electro-mechanical relay bridges the thyristor in the middle of the last pos. pre-magnetisation-impulse, near zero volt, before the full wave begins.
The Thyristor can resist more than 500A, but he don´t see a big current peak, because of the help of the relay.

Emeko Ing. Büro 18

Short circuit is a mere problem for all inrush current limiters.

Not for the TSRL when he is correct fused.

The thyristor inside of TSRL withstands more than 500A eff for 10 msec.
The line protector opens while half wave, 5 msec. after begin of the current peak and limits the current additionally.
But this measured 200Amps peak don’t flow through the thyristor, they flow through the relay contact. And he can handle more than 1000Amps for 10 msec.
And this contact don’t see more than any volts, because of the closing in zero crossing and the minimal bouncing time of less than 1 msec..

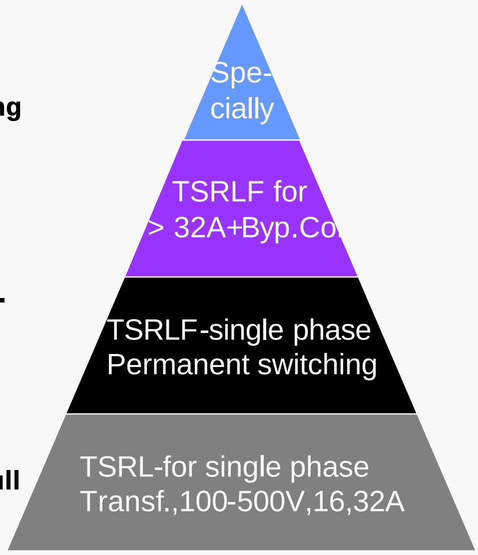
Also exists no problem with short circuits for the TSRL.

Folie 19

View on opportunities of physically correct-switching with **TSR-** Transformer Switching Relay.

For single phase transformers

- **No inrush**, **and switch on with no-load current when unloaded. See measuring curves, picture 16. With load only the load current flows.**
- **Fusing with nominal current and fast blowing when desired. Secondary fuse can be omitted.**
- **No waiting time between switchings.**
- **No inrush after voltage dips. See picture 32.**
- **TSR is short circuit proof. See measuring on picture 18.**
- **More than 5 Millions cycles lifetime under full load with TSRL.**



All types of transformers are switched on without inrush current. Also toroidal transformers are switched on with no inrush. See slide 32.

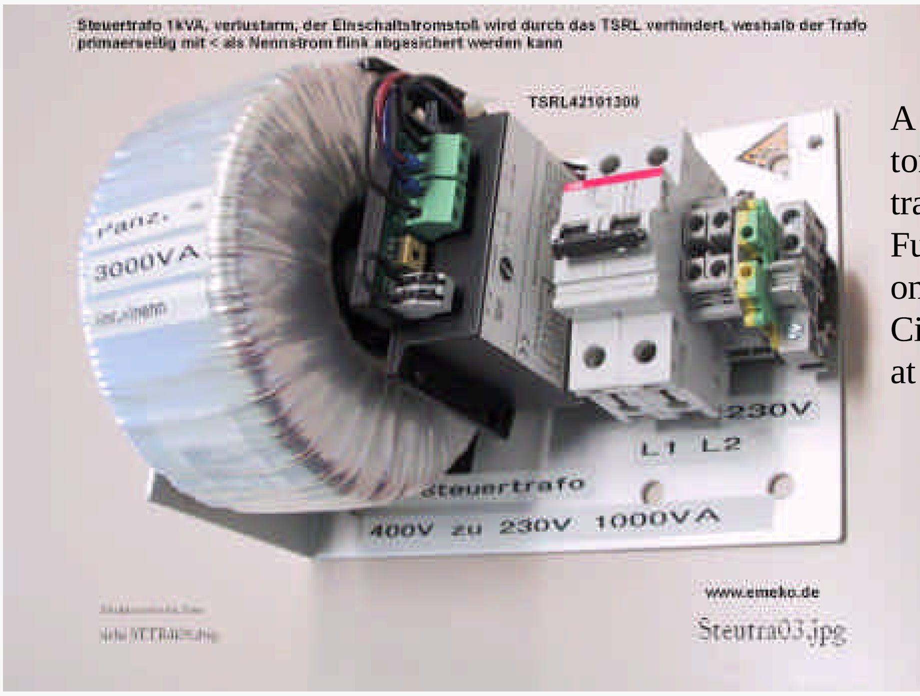
The primary coil can be made with lowest resistance and lowest losses.

Highest induction in core minimizes weight. Handles more than one transformer in parallel. See picture 24.

No permanent losses in TSR, because of electro mechanical Relays bridges the Thyristor. See schematic on slide 17.
With TSRLF types fast cycles applicable. See picture 35, 36.

Folie 20

new type of control transformer with a TSRL.



A 1kVA, 400V toroidal transformer Fused with a only 2A C-Type Circuit breaker at primary side.

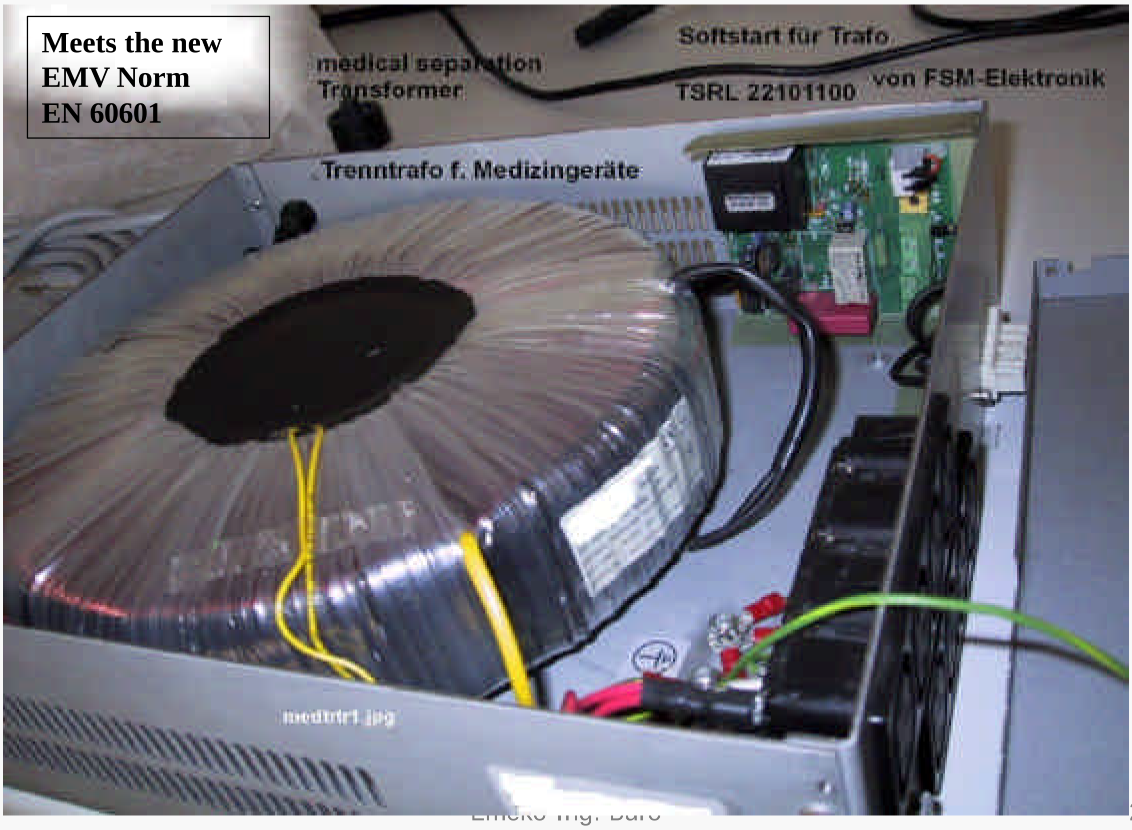
Sample from a customer. The transformer can fused with under nominal current values with fast blowing fuses. Secondary side fuse is omitted.

In the no load state the transformer stays cool, because of the very small no load current of 30 milliamps.

There is a very stiff control transformer with a low voltage drop under load.

Folie 21

medical insulation transformer, with a TSRL print board.



Sample from a customer for medical isolating transformers, with 2 kVA, for a low leakage current to the patient, and for best EMV-behavior.

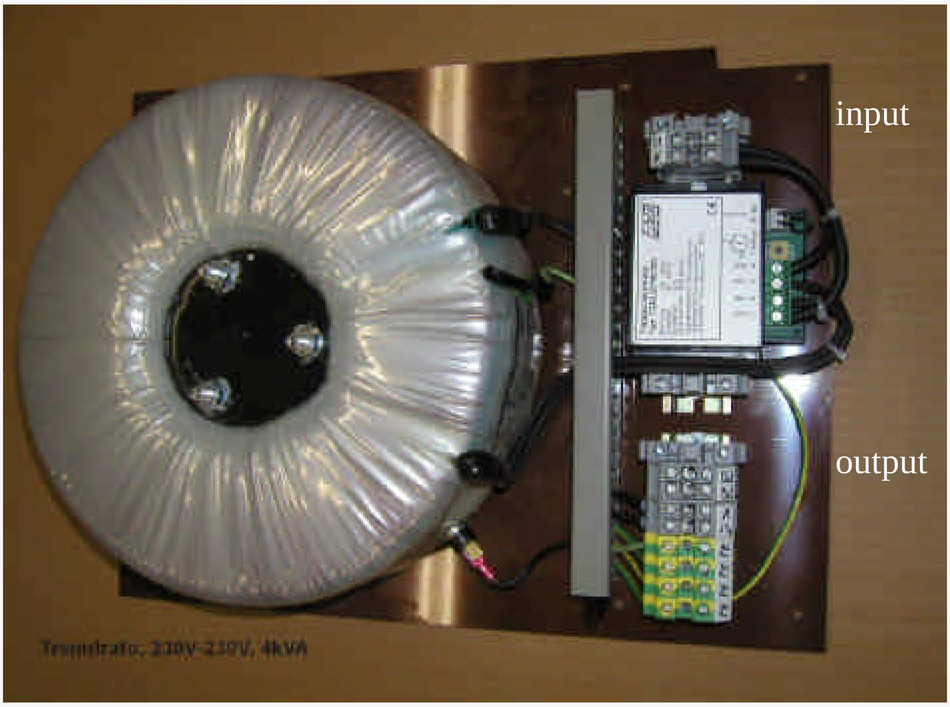
Transformer with low magnetic stray field, over voltage clipping on secondary side and so on.

Meets new medical equipment European Norm EN 60601, also for voltage dips.

This Norm is coming true in November of 2004 for all medical devices.

Folie 22

4kVA insulation transformer with TSRL for 32Amps, transformer is used in fire brigades leader-car and so on.



TSRL
for 230V
32A
45-66 Hz

Sample from a customer.

The transformer is switched on with a no load current of 100 mA

Folie 23

When no cooling is allowed:
When transformers are mounted in a cabinet with no additional forced cooling and no slots in the encasing, than they must have low losses, and when they should not growing up to the double of weight,(for lower the inrush), than the best way is to avoid the inrush current with a TSR and to take a loss optimized transformer.

The best way with lowest losses, while lowest weight is to take a toroidal transformer who is loaded with no more than 50-60 % of his nominal load.

With a TSR the high inrush current of a toroid transformer dont care, he is eliminatedd.

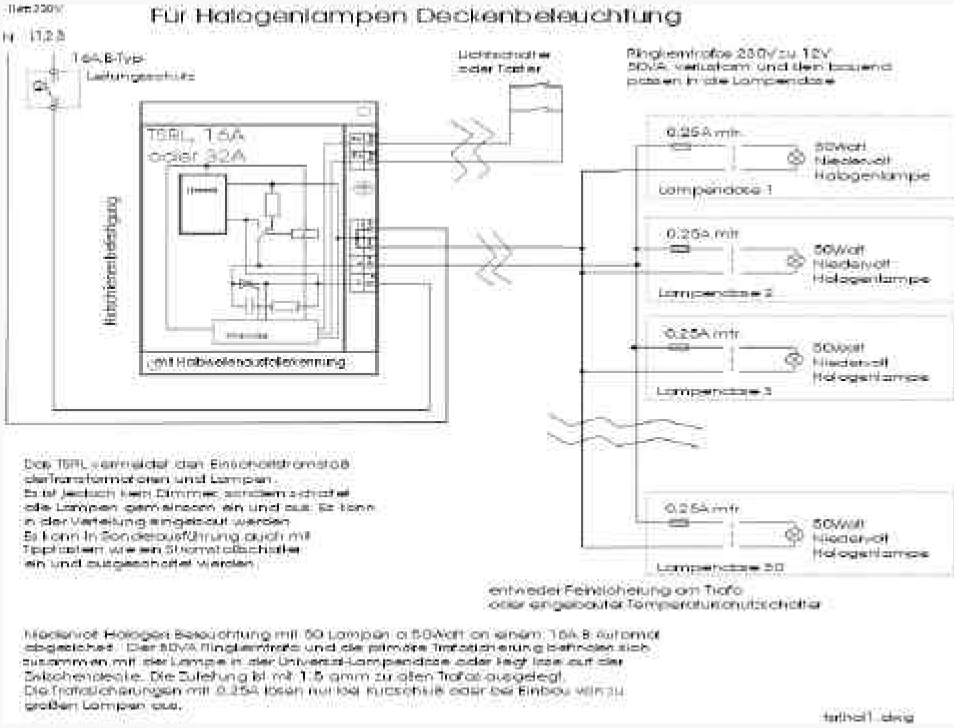
See generally for a clean room application or with an application without expensive cooling devices for the electric cabinet.

To cooling any losses is expensive in clean rooms.

Particularly in summertime, because of the high energy costs for the high rates of cooled air who are blowing to the outside of the building into the environment.

Folie 24

TSRL application more than 1 transformers in parallel.



Sample with a TSRL application for halogen transformers.

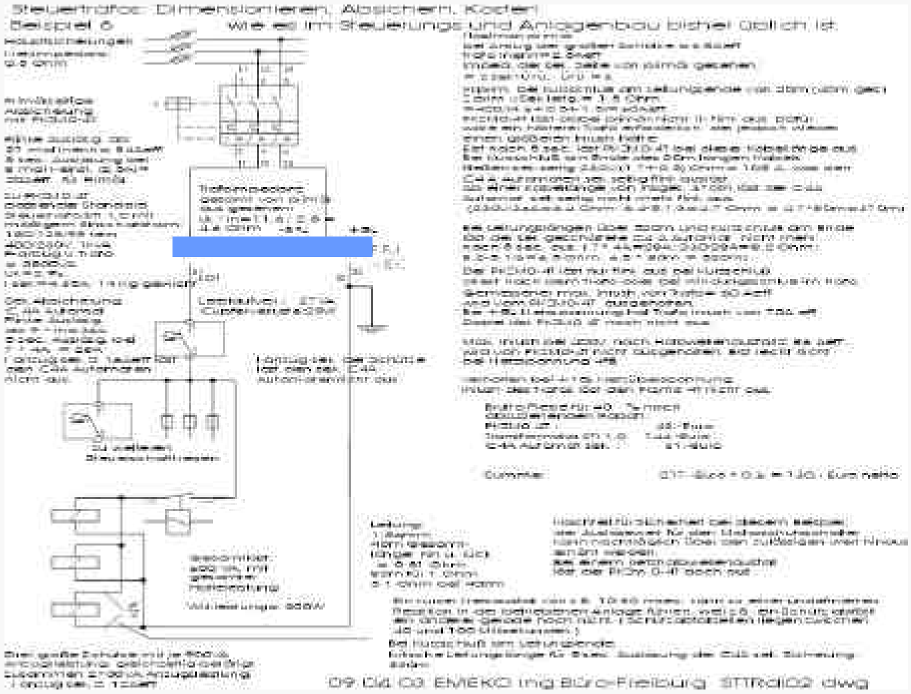
They are situated near the lamps, and will be switched on all together.

The lamps will be also soft start dimmed.

Each transformer has his nominal current fuse.

Folie 25

standard control Transformer schematic.

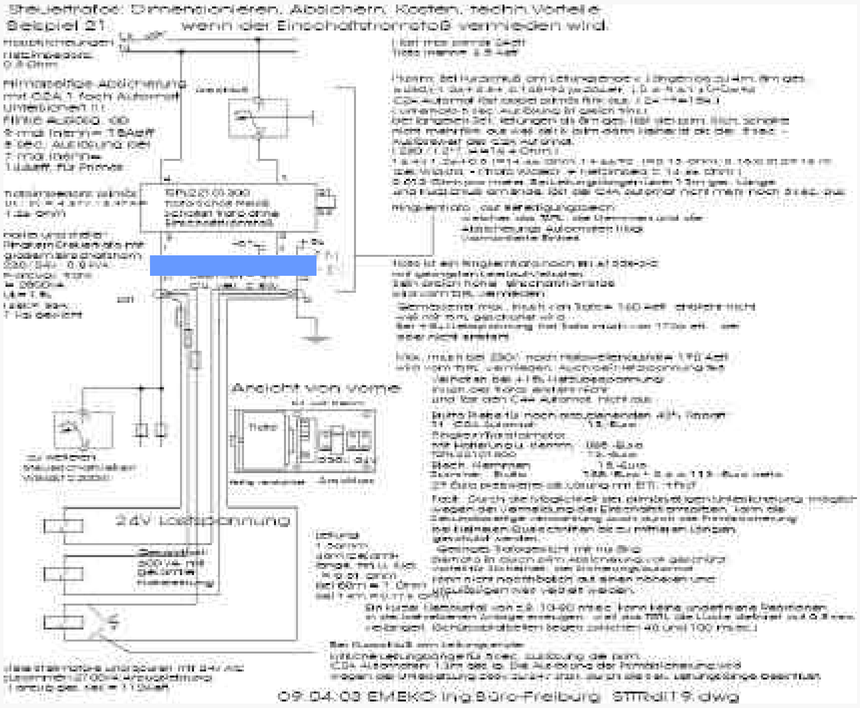


Soft transformerwith conventional fusing

Total costs 130 €

Folie 26

high efficient control Transformer with TSRL.



With toroidal or hard transformer and TSRL Total costs only 113 €

Cheaper than conventional fusing and soft transformer

Folie 27

Comparison of transformer inrush current between **normal switch-on,** and inrush currents following a **Line Voltage dip**, with different types of transformers,

- With soft transformers there is a big difference between normal inrush and inrush after voltage dips.
- With hard transformers the difference between both cases is small.
- See next slides.

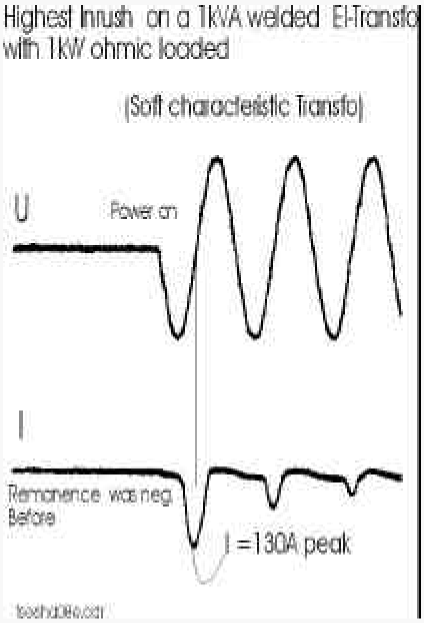
Attention:

Soft transformers with low inrush behaviour when normally switch on, shows high inrushes when feed with power line voltage dips.

Hard transformers with high inrush behaviour when normally switch on, shows no difference between both cases.

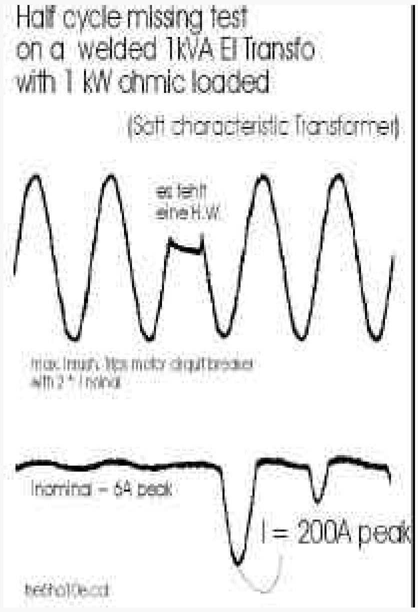
Soft characteristic transformer behavior. (welded core EI- 1kVA measured together with non inductive load.)

Normal inrush is low



Difference is
= 70 A peak

Inrush after voltage dip is high



The inrush after a voltage dip is higher than with normally switch on.

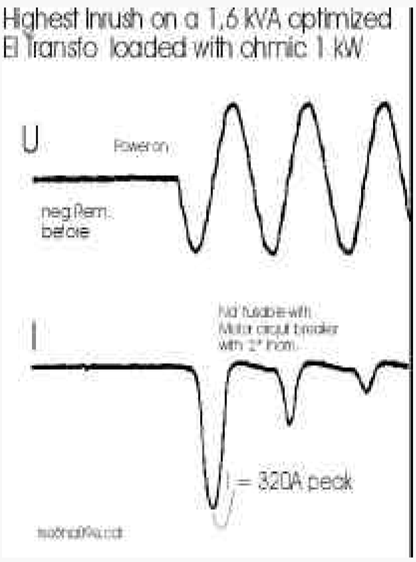
Because of not running back of the magnetisation to the idle remanence point on the hysteresis loop, in a short pause, (when missing a half wave.)

Folie 29

Hard characteristic transformer behaviour.(alternated laminated transformer, (no air gap,) 1,6kVA EI, measured together with non inductive load.)

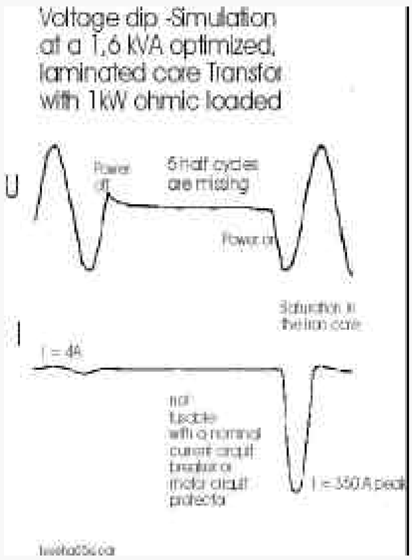
Normal inrush is high

Inrush after voltage dip is high



Low difference between both Cases = **30Apeak**

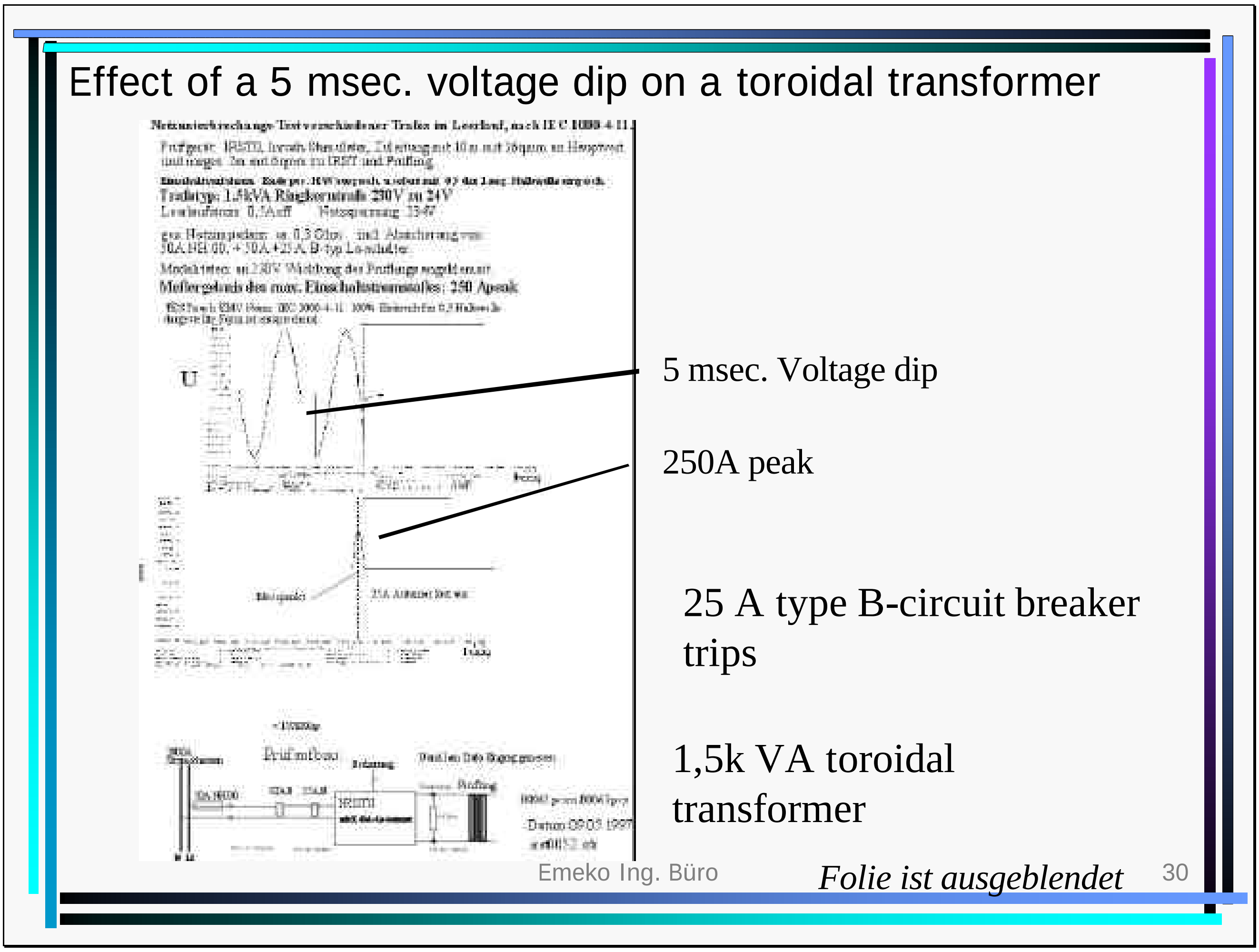
Although the tested hard transformer is bigger than before.



In both cases, when normally switch on or when power line voltage comes back after a short dip, the remanence point has the similar position on the hysteresic loop..

Therefore the inrush is similar.

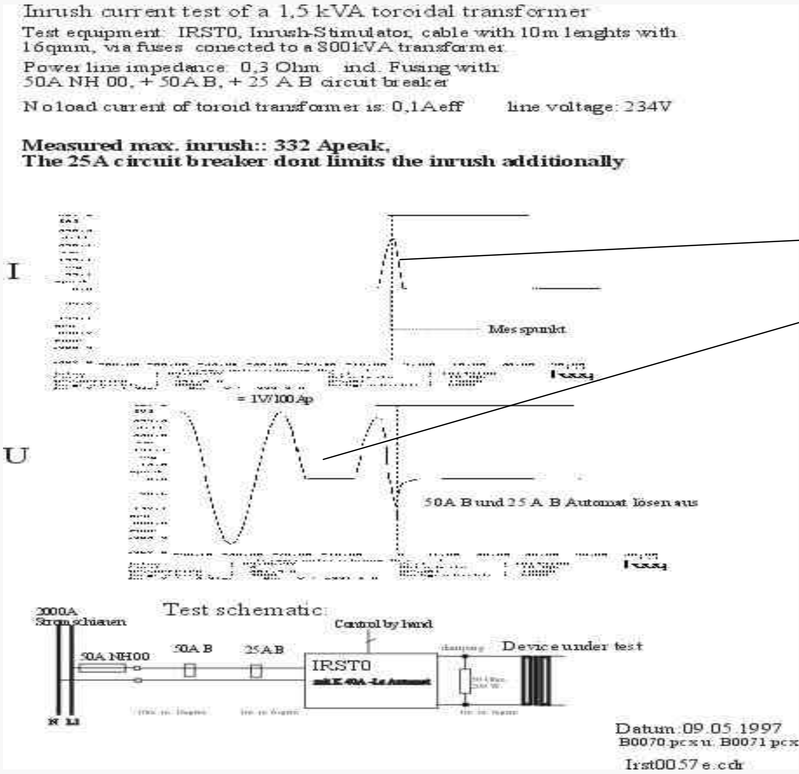
Folie 30



The effect with small voltage dips testing is similar the realistic sags on power lines.

Sometimes fuses are blowing accidentally and nobody knows why, when this happens.

Effect of a 10 msec. voltage dip on a toroidal transformer



332 A peak

10 msec. voltage dip

25 and 50A type B circuit breaker trips

1,5 kVA toroidal transformer

Biggest inrush of transformer.

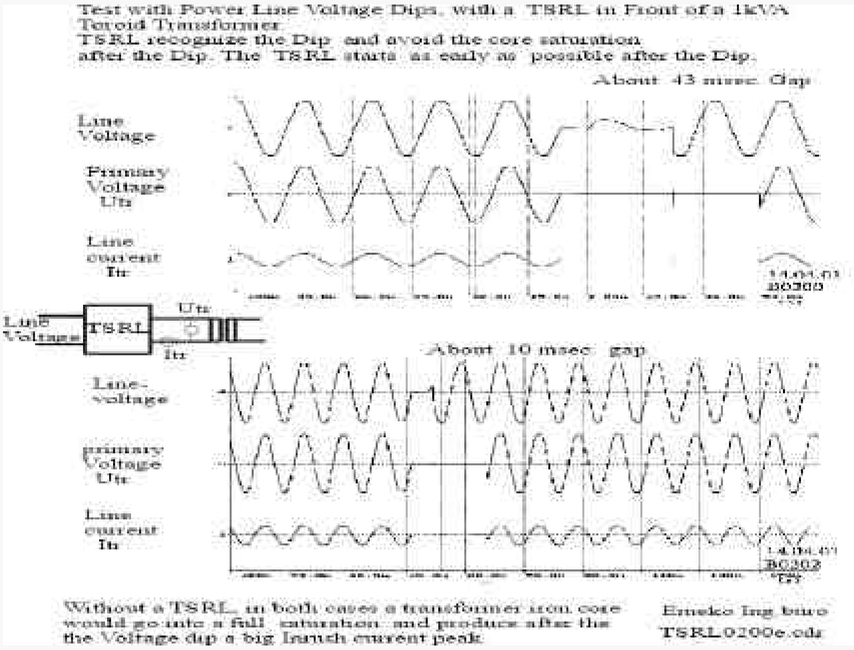
Bigger than with normal switch on in the worst case, after a long time pause.

While the short time of a voltage dip the magnetisation can not run back to his stable remanence point in this short pause.

Therefore the core saturation is higher than with normally switch on, when the power line voltage comes back.

Folie 32

Effect of voltage dip with a TSRL with fast half cycle dip recognition option.



With the same transformer as tested before

Fast reaction of TSRL protects the transformer from saturation

Fast switch on, at nominal current

Emeko Ing. Büro

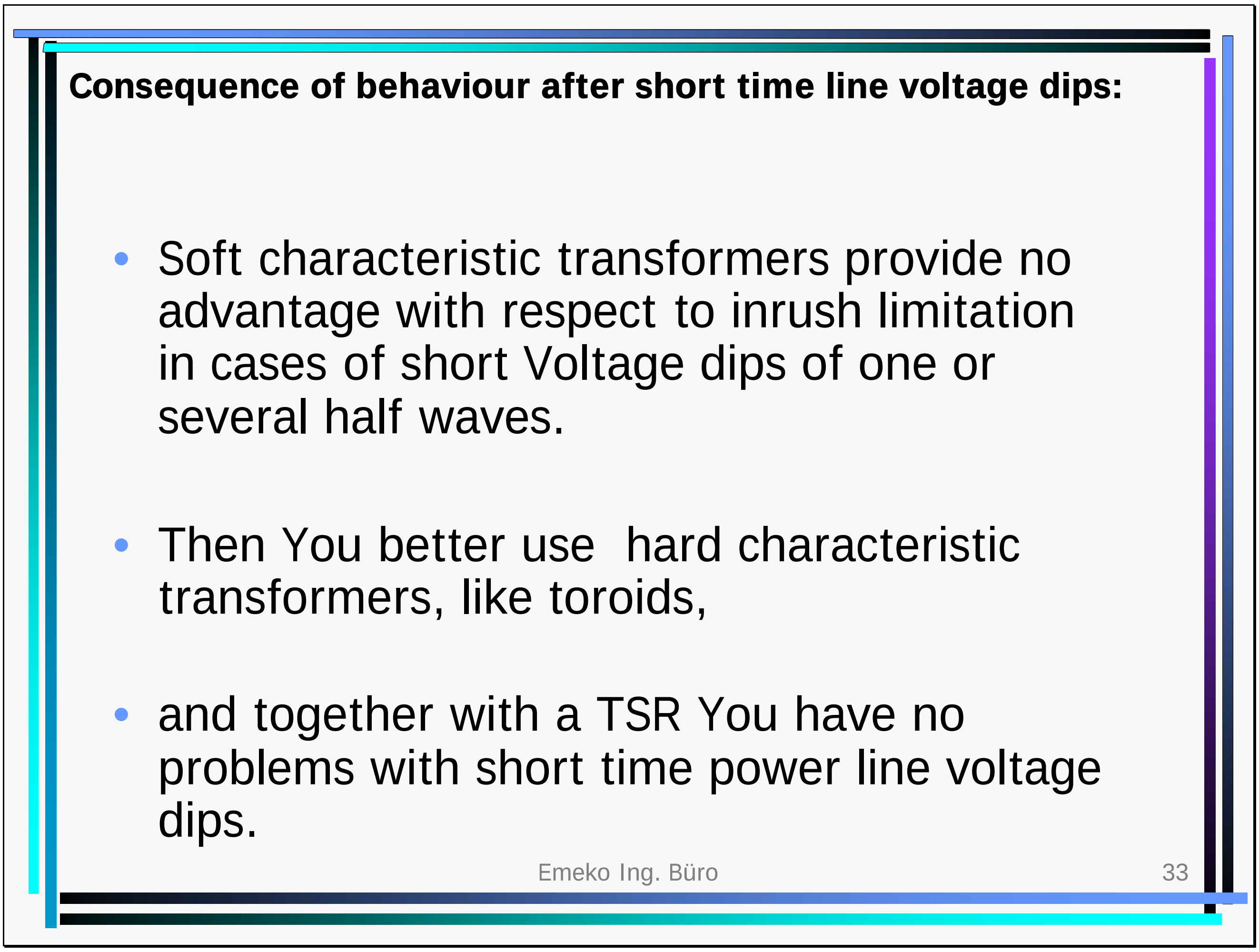
32

The effect of inrush after short time line voltage dips, can be avoided with a TSRL with the option: -----

----- „ schnelle Halbwellenausfall Erkennung.“= fast reacting on voltage dips and fast switch on after voltage coming back.

The voltage gap at the transformer will be about 20 msec. longer than the power line gap.

Folie 33



The consequence is hard for soft transformers.

They lead to use hard transformers together with a TSR.

Folie 34

The best hard characteristic transformer that I know is a toroidal transformer.

A toroidal transformer brings much advantages, like lowest iron losses, lowest no load current, lowest weight, low copper losses,(-can be implemented if inrush current is avoided by other means,) and a toroidal transformer brings also other advantages..... But it has also a big disadvantage.....
He has the highest inrush current peak. Up to 100 times the nominal current. See measuring curves on slide 2, 3.
But You have **no inrush** with a toroidal transformer when he is used together with a TSRL, See picture 16, 32.

When inrush current peaks can be avoided with a Transformer-Switching-Relay, then the toroidal transformer can be the best choice. Its no load current and losses are more than 50 times lower than with welded EI core transformers.

The most prejudice against toroidal transformers refer to high inrushes and to loose wires into the windings.

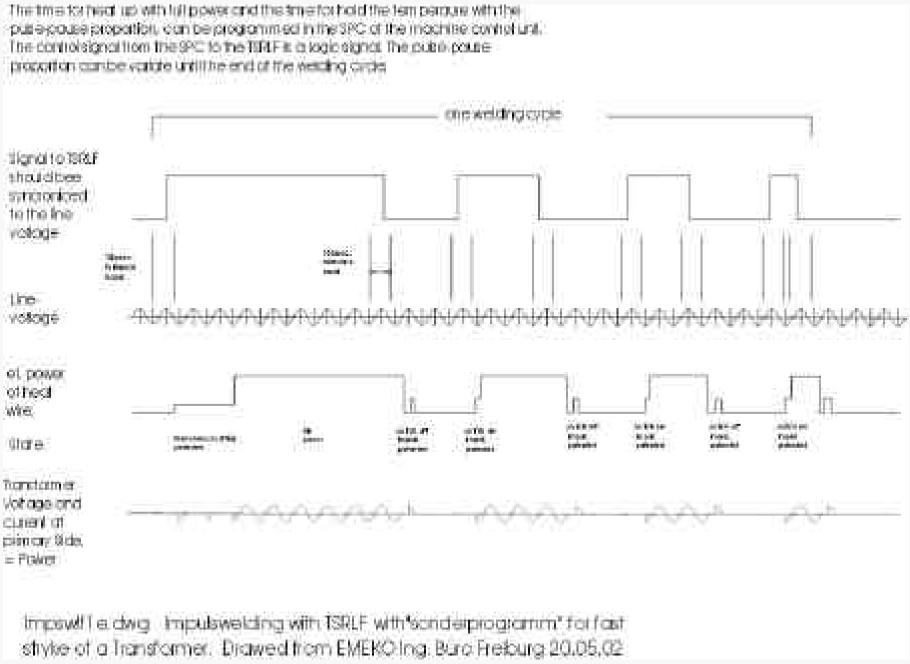
Subsequent from inrushes when the coils are not impregnated with resin.

(The inrush produce high forces inside of windings and leads to loose wires. Loose wires leads to shorted turns in the transformer windings, because of wire movement while inrush. Then the transformer is defect.)

All that negative points are eliminated with a TSR.

Folie 35

fast cycle pulsing of transformers and load with TSRLF as control module and a random switching ELR.



For low voltage heating. Power control with fast pulse groups

Current into transformer is not reactive

Schema of pulse groups to a transformer, the bottom line.

Also toroidal transformers can be switched like this, because of resetting the remanence after each switch off and correct setting while switch on.

See current curves into the transformer to see in the bottom line.

Folie 36

application of TSRLF for 12 units of low volt heating zones for a plastic foil heating plate.

12 units of TSRLF controls 12 units of toroid transform.

Each transformer has 250W and 230V to 32 V.

Sample from a customer with the switching procedure showed ahead.

Folie 37

Now about 3 phase transformer soft start with TSRD and TSRDF

They can start a 3 phase transformer with no more than the periodic no-load current peaks.

Facilitates the use of fast acting circuit-breakers with nominal current of the load.

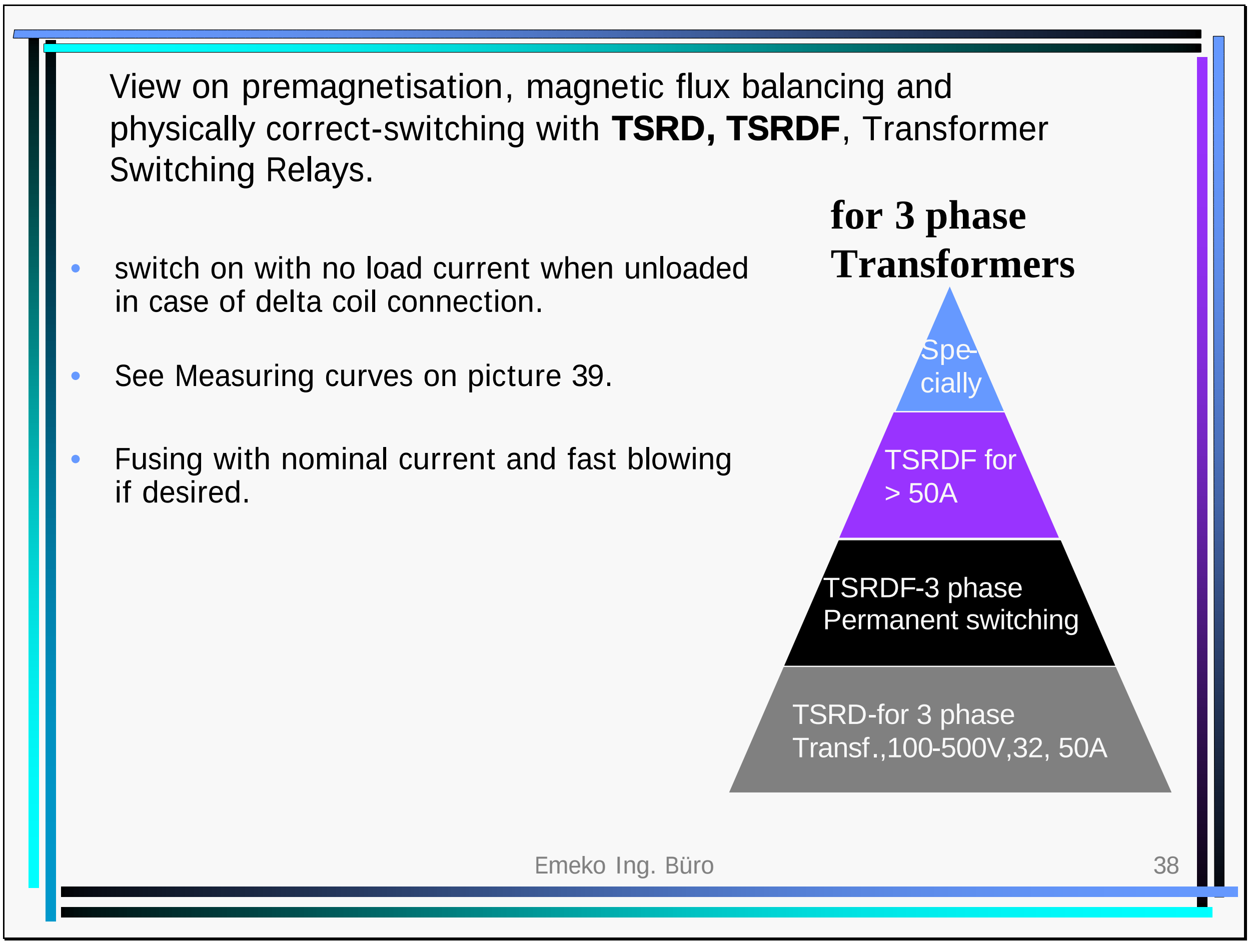
Short circuit proof.

No heating up of the TSRD.

Needs no pause between soft starts.

For 3 phase transformers with primary voltages up to 500V.

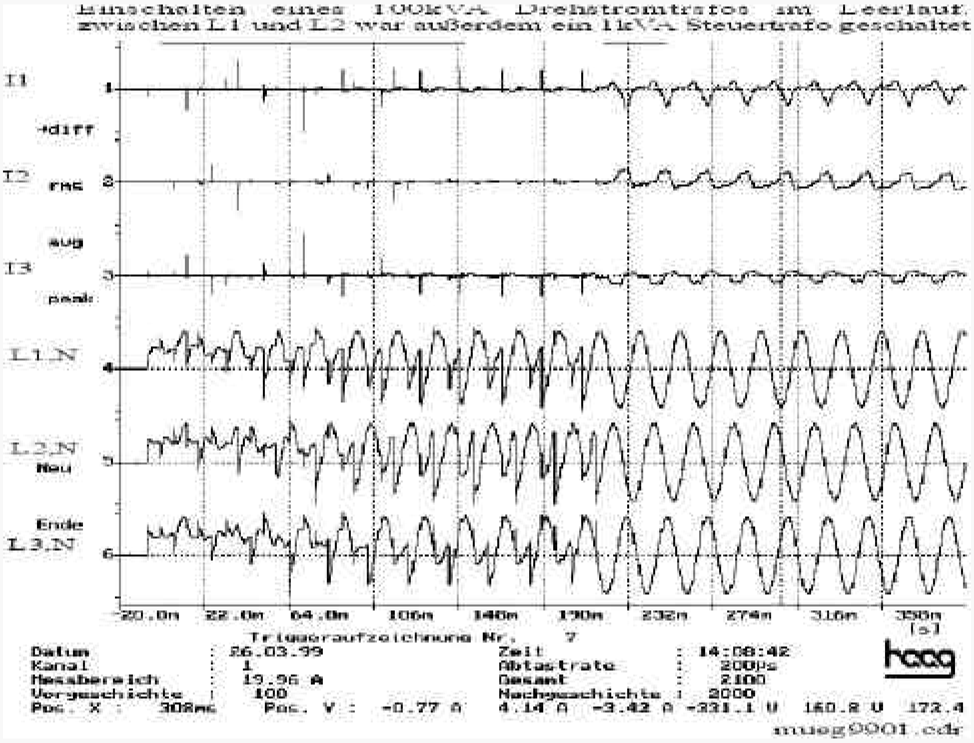
Folie 38



Same opportunities like with single phase transformers.
Primary coil can be designed with lowest resistance and lowest losses.
High flux density in core provides lowest weight.
No waiting time between switching.
Control input allows to control.
Short circuit proof, when TSRD is fused separately with fast acting fuses.
Available from 100V – 500V, from 32A – 500A.
Function is load in-dependent.
Handles more than one transformer in parallel.
More than 1 Million cycles lifetime under full load of AC1 bypass contactor, with no arcing.
No permanent losses in TSRD, because of bypass contactor.

Folie 39

3 phase Transformer switch-on current diagram.



With a 100 kVA Transfor-mer, only a 4A peak starting current appears,

That´s the no load current.

The low switch on currents are important to look.

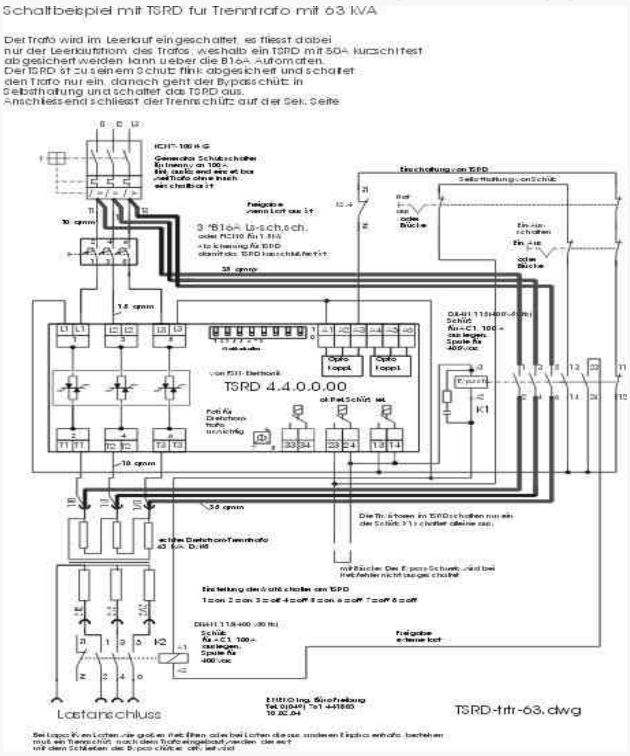
There is only the no load current value.

In the middle of the diagram the transformer is switched full on.

See full voltages up to now.

Folie 40

Schematic for a TSRD in a 3 phase application.



The TSRD for 24 kVA only starts the 63 kVA transformer, the bypass-contactor handles the permanent current and the overload and short circuits.
The load separation contactor must be used when transformer is under load while switch on with a cheap TSRD with to small thyristors for the load current.

After switch on, the bypass contactor is treated to closing, he brings himself into self-hold and switches the TSRD off.

In case of overload, short circuits and so on the TSRD is well protected.

TSRD in a 3 phase application.

80 kVA Transformer

for adapting and for Insulation the load. (3 * 400V to 3 * 225V) The transformer has low losses, because he is placed in a clean room of a silicon wafer -factory.

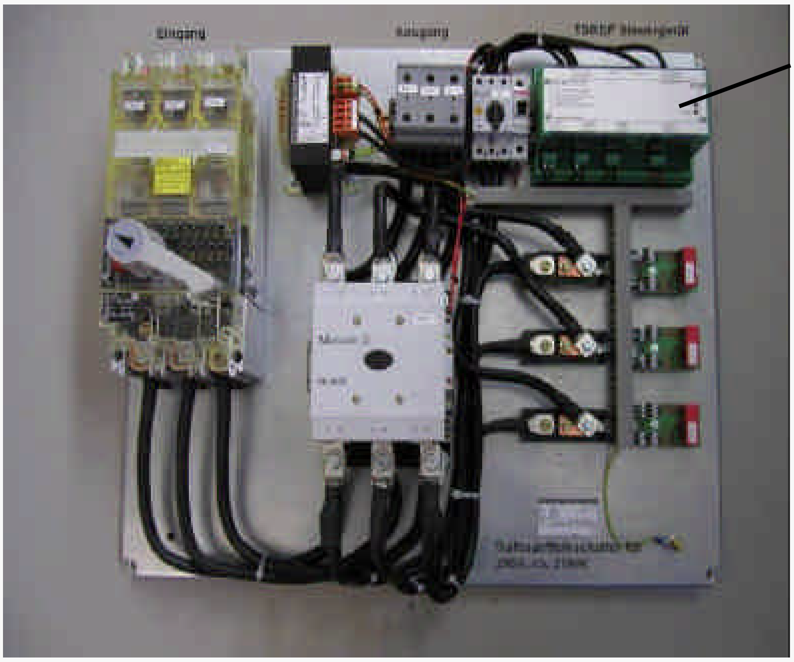
Assembled with TSRD and bypass contactor and fuses.

Sample of a customer in a clean room, for adapting the german powerline voltage to the USA equipment.

The inrush elimination is important for the alternativ emerging power source, a diesel generator.

Folie 42

TSRDF-Booster, for 250 Amps.



TSRDF control box
from FSM-Elektronik

Unit can start big
transformers up to
160kVA
together with load
only with
the load current-
peaks at the start.

Assembled by
Trafo-Schneider
March-Buchheim
in Germany

Sample of a customer for a building site isolation transformer.

Folie 43 ab hier kann auch zum Ende, zu Folie 47 gesprungen werden.

Cost Analysis

- The current consumption costs for the end-user are lower when he gets a consumption-optimised transformer with lower losses and in conclusion with TSR inrush avoiding.

- When tested with line voltage dips like EN 61000-4-11, EN 60601, no other inexpensive solution like a TSR exists for single phase transformers.

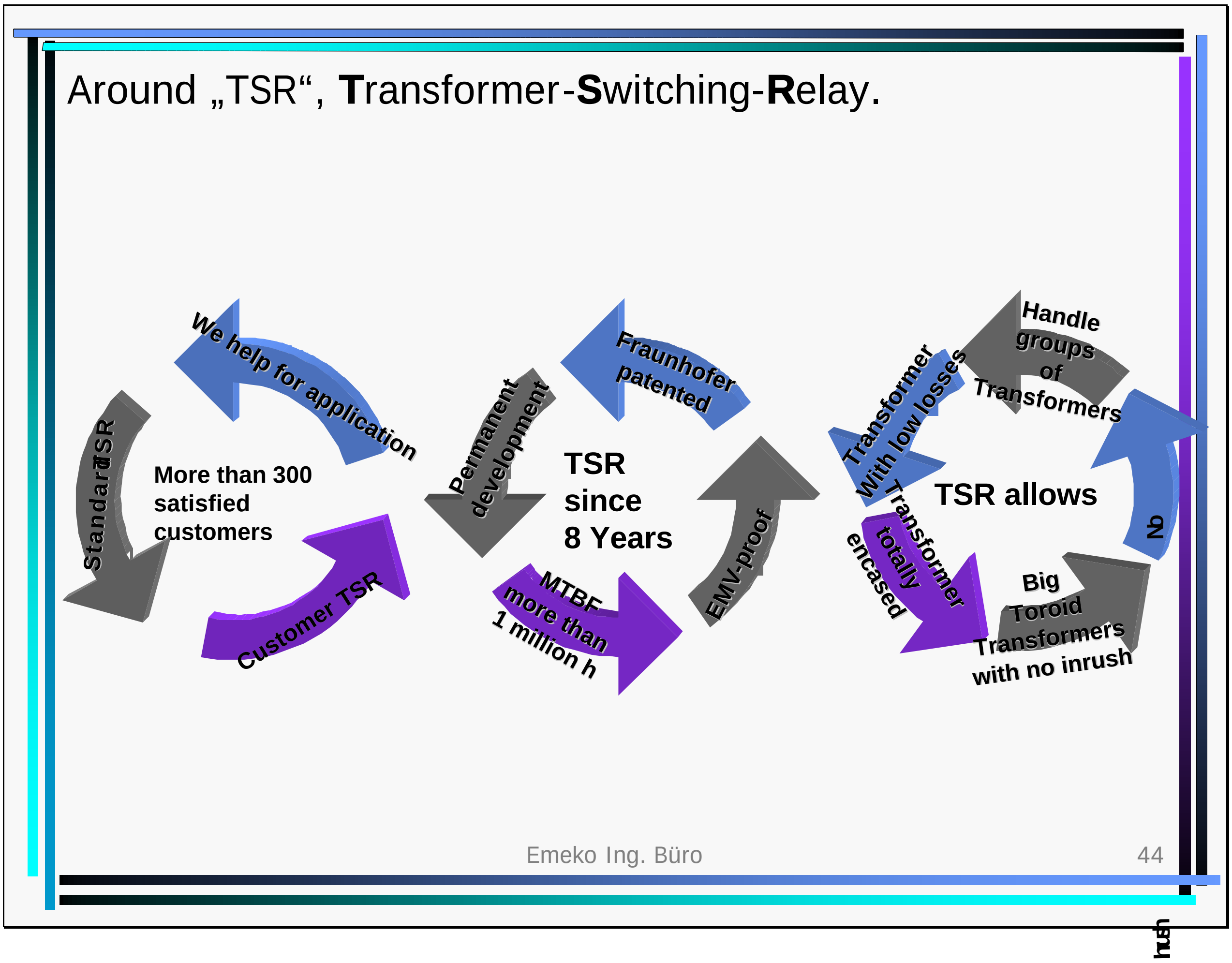
Important are the loss consumption costs over the years.

That is of interest for the end user.

See schema on picture 25, 26

Depending on case to case, the initial costs can be higher or lower with TSR, depending on fusing, transformer, cooling units., life time and so on.

Folie 44



A bundle of opportunities

Folie 45

Most important advantages of TSR. –Summary-

- Avoidance, not only limiting of inrush current peaks.
- The consequence is no more dealing with restrictions in design of transformers, taking regard of inrush current peaks .
- Allows design of transformers with lower losses .
- Allows totally encapsulated transformers without air fan exhaust or cooling slots in encasing. (clean room application.)
- No pollution of power lines, with voltage sags from inrush current.
- Avoids burning of transformers due to incorrect fusing.
- Fast cycle acting with pulse groups for industrial heating with low volt high currents. (Direct electric heating of tubes with TSRLF or TSRDF.)
- Replaces expensive conventional thyristor regulators in many cases .
- Allows low weight portable transformers, insulation transformers in cars, see pictures 20, 21, 22.
- With TSRL and TSRLF avoids Inrush after power line voltage dips, tested with En61000-4-11. See measured curves on picture 32.
- TSR helps toroidal transformers with more than 300VA in many applications.
- No difference in function between no load state and load state

Repeating of the most important points for TSR.

Folie 46

Possibilities for You.

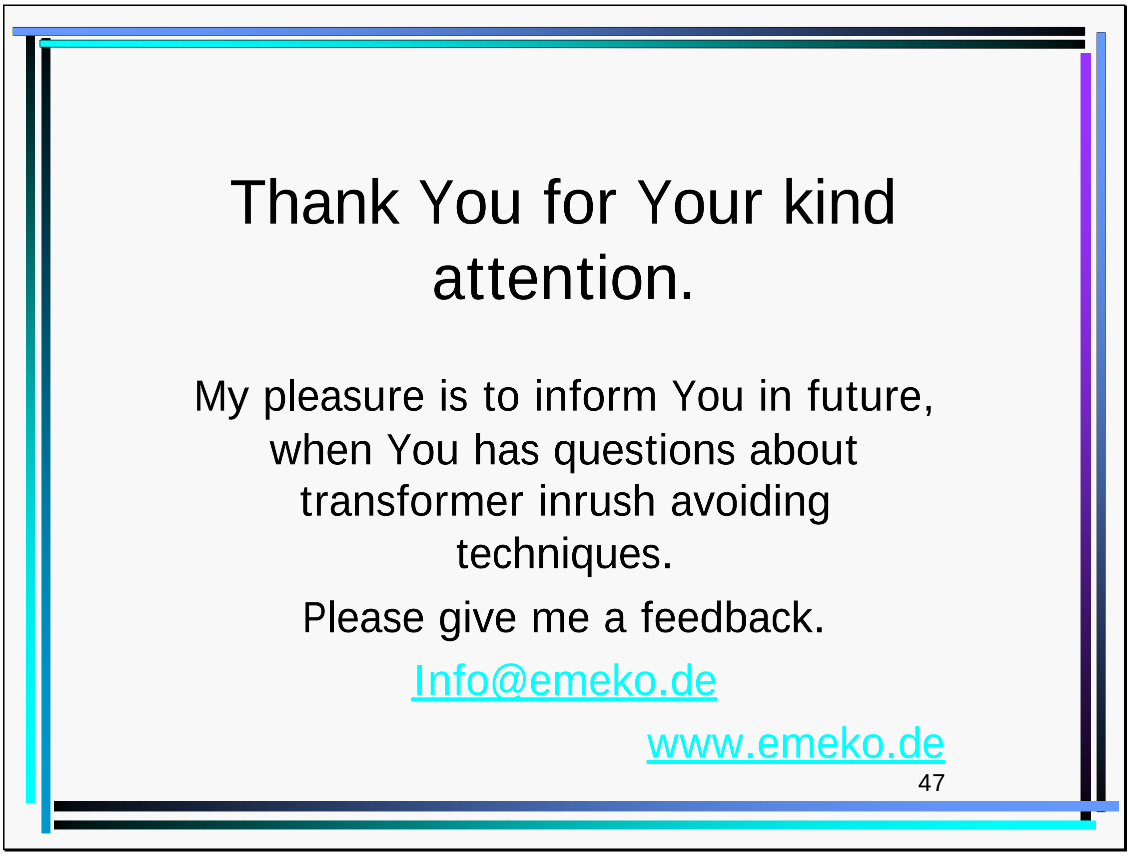
- You can offer to Your customer a new and prooved solutions of an old problem.
- Now time is here for TSR to eliminate the inrush current. Good EXPERIENCE with many thousands of TSR since more than 8 Years.
- Measure the true inrush current peak of your transformers. You will be amazed if You compare the measured values with the calculated inrush current peaks from Your „transformer design program“. Most programs calculate the Inrush peak to low.
- For many apparatus the EMV rules EN61000-4-11, EN60601, becoming valid in November of 2004. Then apparatus also with transformers must to tested with short time power line voltage dips. (1 half wave of a cycle is missing, beginning in zero and ending in zero. That brings max. saturation in the core and a higher inrush like first switch on.) Also here TSRL and TSRLF helps to avoid inrush current peaks.
- Test a sample of a TSR, You will see the opportunities and You will be satisfied.
- If you produce or deal with toroidal transformers, a TSR is a good help to solve the inrush current problem without disadvantages. With TSR: no waiting time after switch off and on, no permanent losses and no unwanted higher impedance like with NTC. And if some things are going wrong: TSR is short circuit proof, when correct installed.

In lately 5 Years the current consumption costs are raising to higher values.

Then it is important to have transformers with low consumption of losses. –Like low loss motors.-

Than a TSR helps to use low loss consumption transformers.

Folie 47



The END of speech. Freiburg, the 08.06.2004. Michael Konstanzer