EAF SMARTrafo Solution

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Agenda

- Introduction
- Life cycle cost model
- SMART Transformer
- Numerical study
- Conclusions

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Company History

1916
- Tamini starts its activities in Milan, producing small oil immersed transformers

1961
- Production is moved to the new Melegnano premises

1988
- Acquisition of Novara-based Verbano Trasformatori S.r.l.

1991
- The Company acquires former OEL facilities in Legnano

Since 1916:

A Century in Energy Applications

1995
- Acquisition of Veneta Trasformatori Distribuzione S.r.l. (now V.T.D. Trasformatori S.r.l.), based in Valdagno (Vicenza province)

2000
- The Group establish a commercial entity for the North American market, Tamini Transformers USA

2006-2010
- In 2006 the Group started a €20m investment plan to revamp the Legnano plant

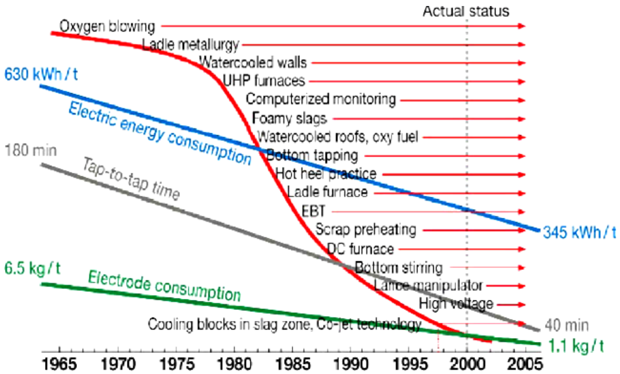
2014
- The Group has been acquired by Terna Group

2015
- The Group finalized the business combination with TES Transformer Electro Service S.r.l., based in Ospitaletto (Brescia province)

Electric Arc Furnace (EAF)

- PAST - Main improvements in energy performance:
  - Reduction of Power Off time
  - Reduction of Tap-to-Tap time
  - Chemical energy use
  - Foamy slag production
  - Electronic adjustment of the electrodes
  - Increasing of arc voltage and use of reactors to stabilize
- Energy still represents a significant share of the total costs
- TODAY - New improvements in the EAF process are difficult to obtain
  - Needs of improving other components of the system: i.e.

    EAF Transformer

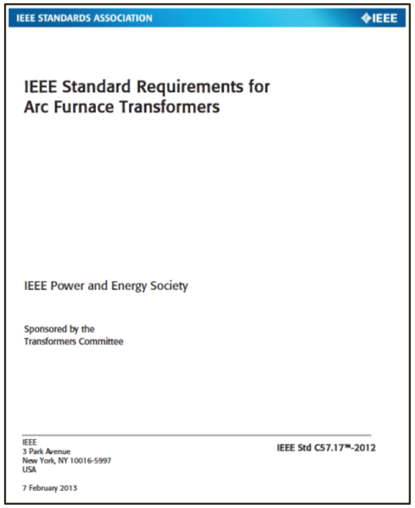


EAF Transformer

- EAF transformer are exposed to more critical conditions than any distribution transformer
  - Very high secondary currents and low secondary voltage
  - Heavy current fluctuations and unbalanced conditions
  - Switching transients
  - Harmonics
  - Short circuits
  - Mechanical stresses
  - Frequent overloading conditions
  - Vibrations
  - Pollution & Dust

Literature Review

- Transformer is a consolidated technology but is still subject to research on control/monitoring systems and working conditions
- Optimisation of EAF Transformer is a recent topic with increasing interest by the research community
- LCC model for transformers are widely available in literature but non of them is focused on EAF Transformers


IEEE STANDARDS ASSOCIATION

IEEE Standard Requirements for Arc Furnace Transformers

IEEE Power and Energy Society

Sponsored by the Transformers Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std C57.17™-2012

7 February 2013


SYSTEM FOR REAL-TIME MONITORING OF THE TECHNICAL STATE OF A TRANSFORMER ON AN ULTRAHIGH-POWER ELECTRIC-ARC STEELMAKING FURNACE

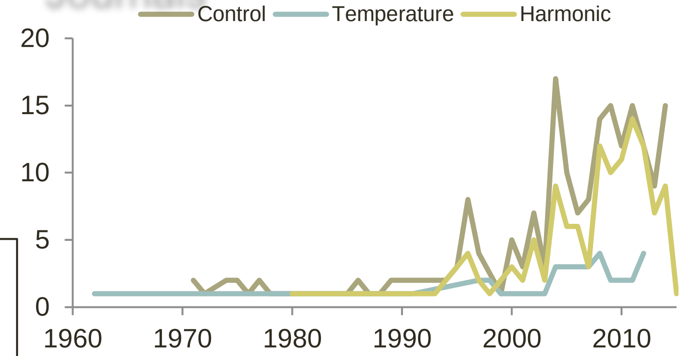
Effects of Main Transformer Replacement on the Performance of an Electric Arc Furnace System

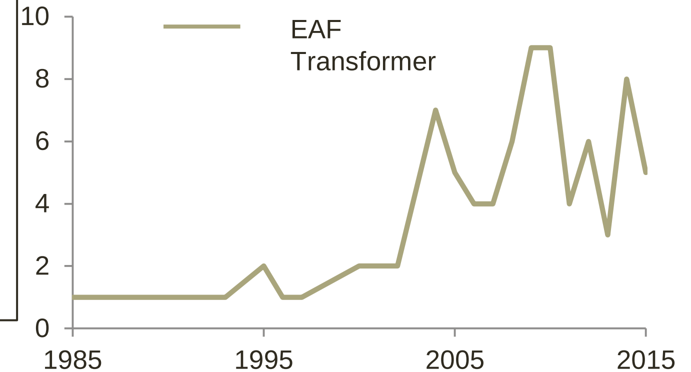
Energy

Maximizing the transferred power to electric arc furnace for having maximum production

Haidar Samet, Teymoor Ghanbari, Jafar Ghaisari

Papers appeared in Scientific Journals

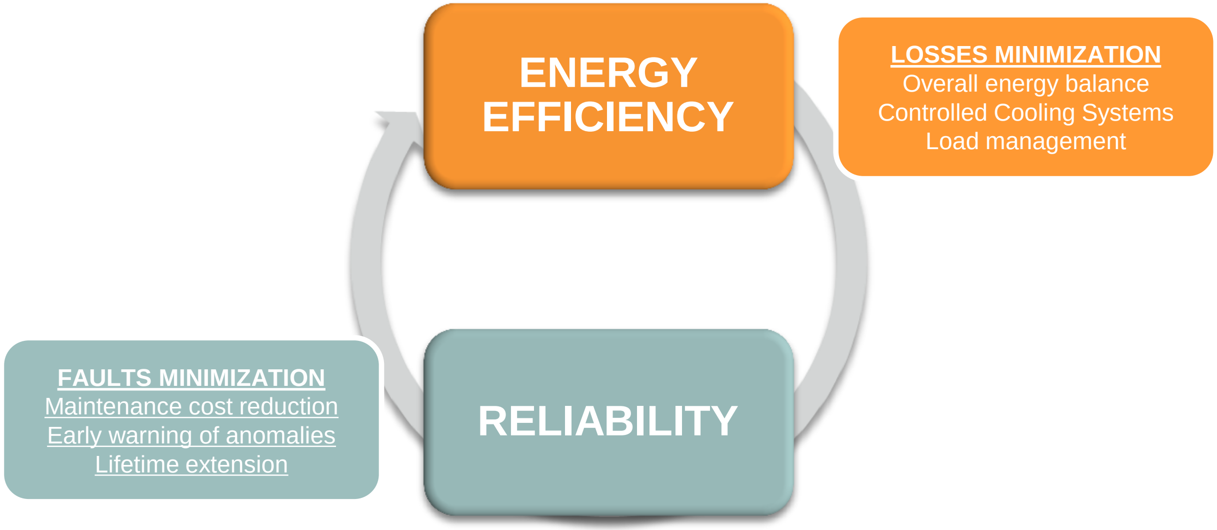




Keywords search performed with: Scopus

Goal

- Development of a Life Cycle Cost (LCC) model considering relevant aspects for EAF context
  - Impact of operating conditions
  - Maintenance activities
- In order to select the best design solution for a specific load cycle



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LCC model

EAF Transformer price

Operating costs

- Energy losses costs
- Cooling system costs

$$LCC = EAF\ Transformer\ price + \sum_{i=1}^{n} \frac{Ownership\ cost + Maintenance\ cost}{(1+\rho)^i}$$

Maintenance costs

LCC model

EAF Transformer price

- Transformer → capital intensive equipment
- Price results of
  - design specifications
  - additional equipment

Operating costs

- Energy losses costs
- Cooling system costs

Maintenance costs

LCC model

$$Energy\ losses\ [kWh/cycle] = P_0 + P_k \sum_{j=1}^{m} x_j^2$$

EAF Transformer price

Operating costs

- Energy losses costs
- Cooling system costs

Maintenance costs

- No-load losses
- Load losses
- LV terminations losses

- On service vs laboratory conditions

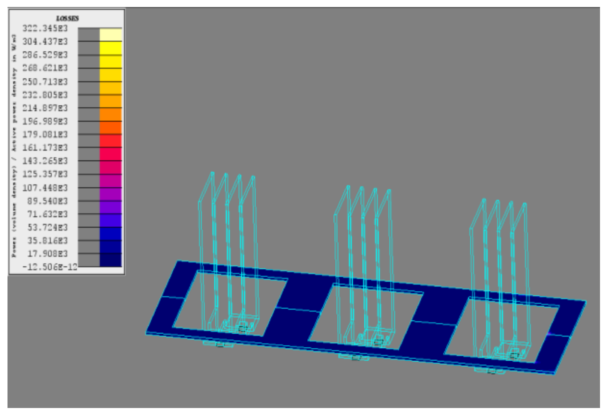
TAILOR MADE CONFIGURATION

- Cooling system control
  - Without → Oversized cooling power
  - With → Modular utilization
- …

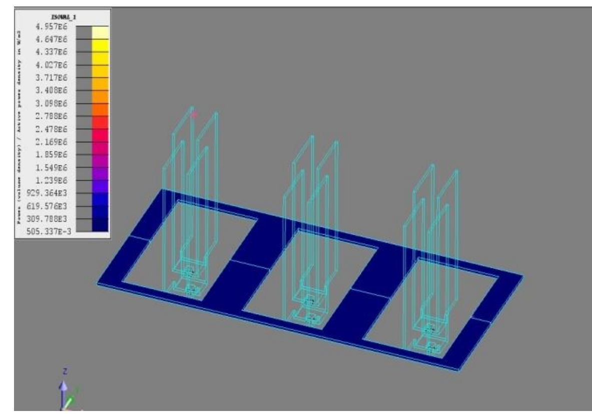
Example 1:The Low Voltage terminations

- Low Voltage bus bars/pipes 
  - losses evaluation with FEM Model for two different layout options

Symmetrical



Not symmetrical

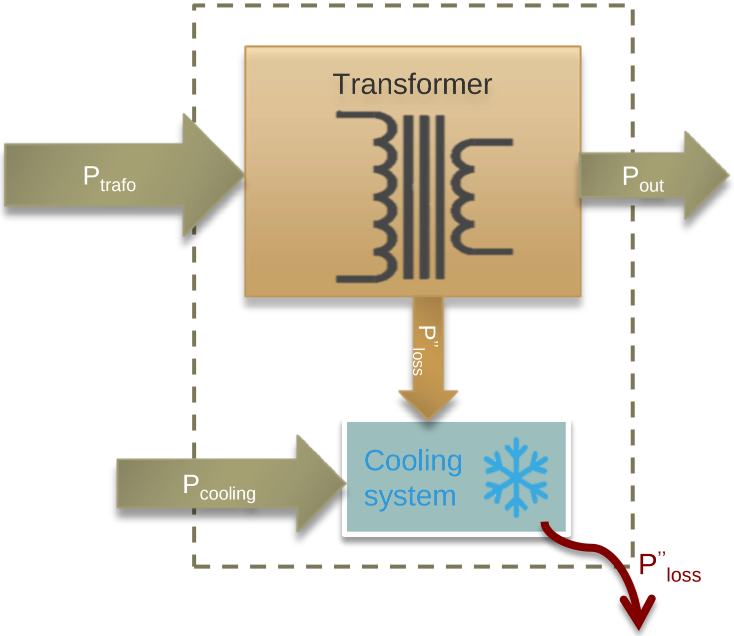


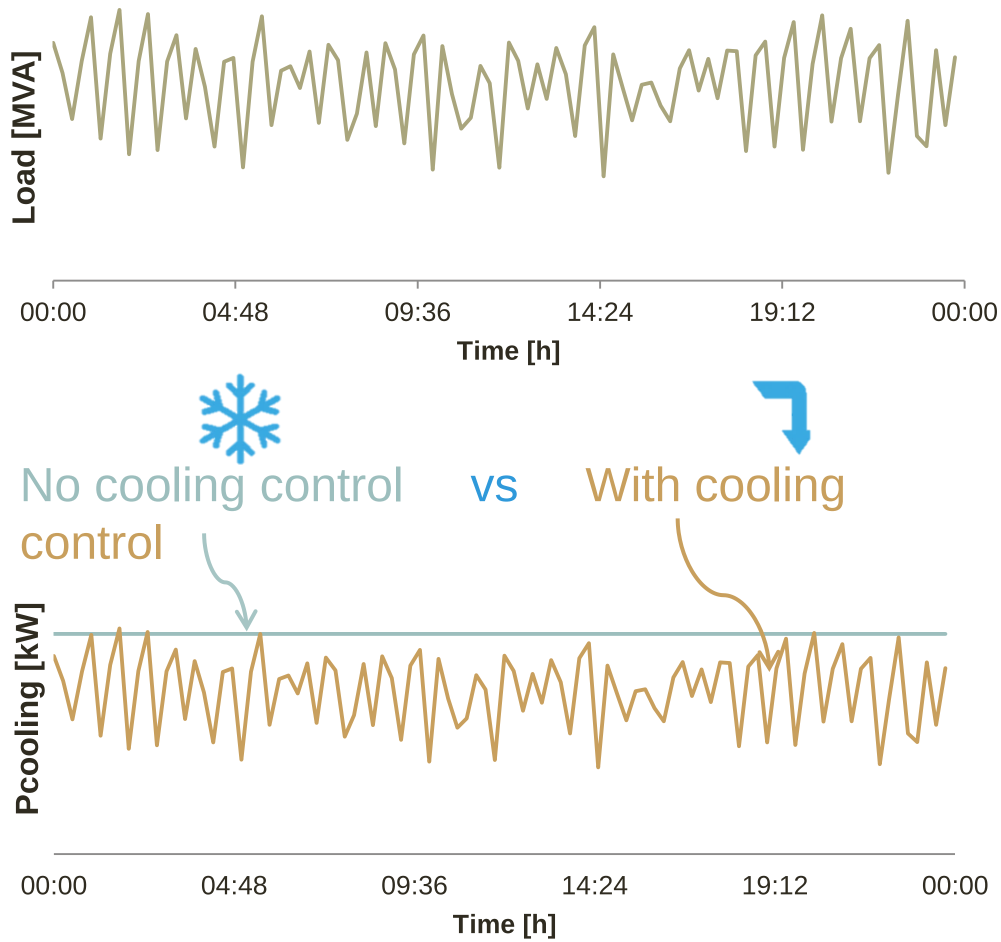
Losses	In the cover	1 kW	4.5 kW
	In LV bus bars	54 kW	74 kW

+43%

The bus bars arrangement can drastically increase the losses and oblige to select expensive solution

Example 2: The Cooling System Effect





LCC model

EAF Transformer price

Operating costs

- Energy losses costs
- Cooling system costs

Maintenance costs

- Maintenance activities
  (i.e. inspections and actions performed)
- Out-of-service
  (i.e. steel production lost due to downtime)
- Reliability penalty
  (i.e. replacement of the transformer due to failure)

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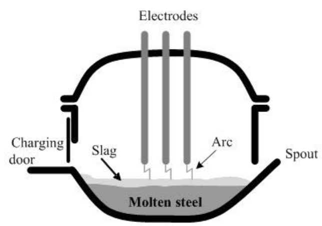
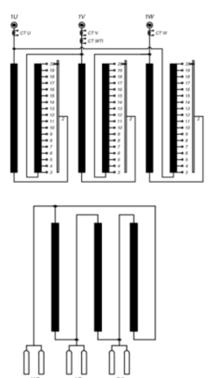
Why a SMART Transformer?

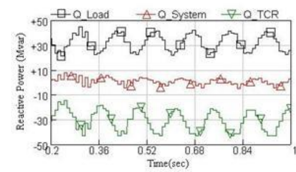
- Use condition (EAF) affects the design customization of the EAF Trafo

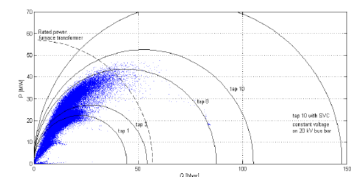
EAF



TRANSFORMER







Load variability

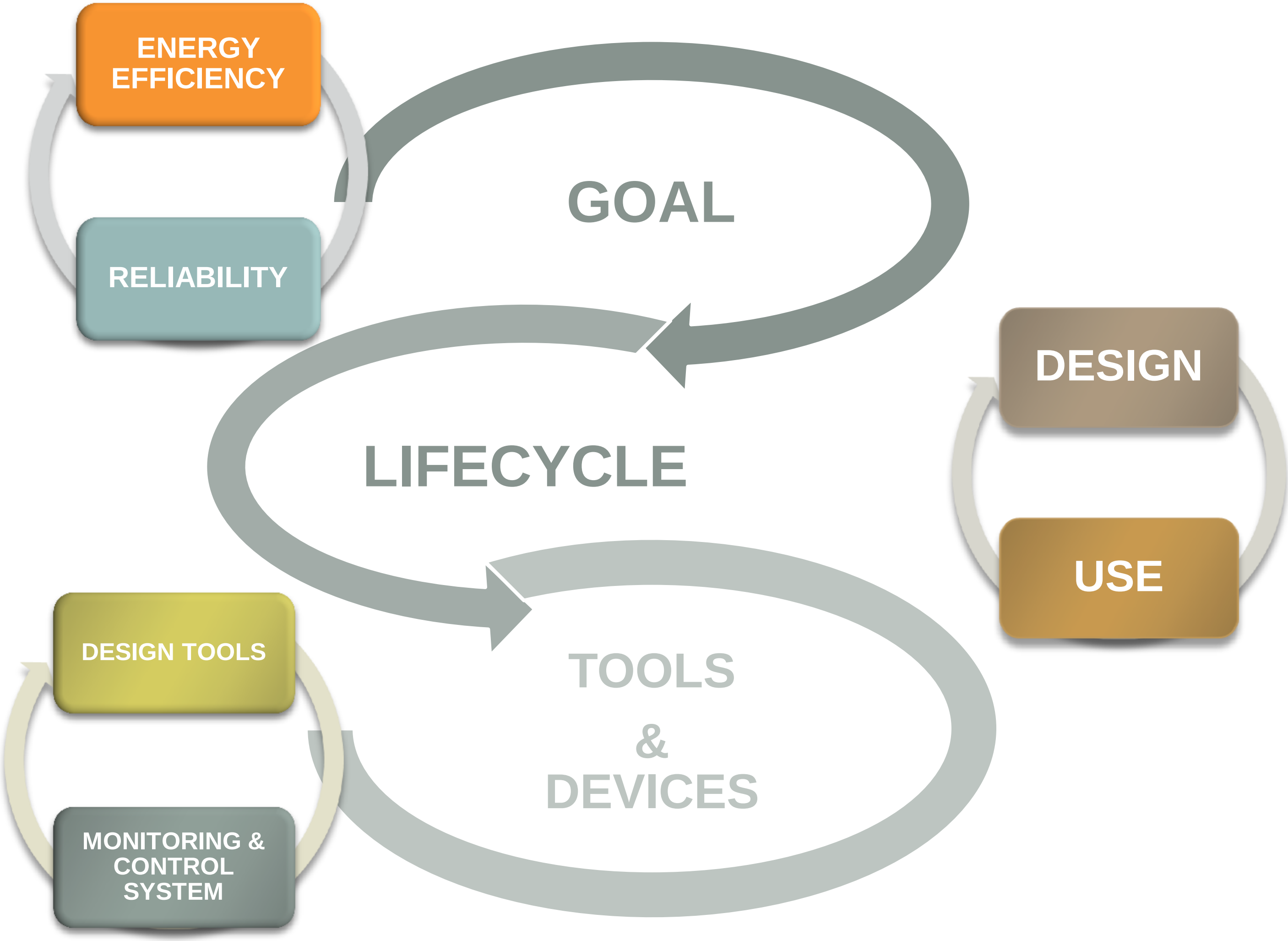
Tap positions

OLTC

Active parts

Cooling system

SMART Transformer Approach



Design and Use

DESIGN

- Design principles
- Tailor-made solutions (On-service operating conditions)
- Materials selection
- Components & Accessories

Main aspects:

- Secondary Voltage range
- Number of taps
- Short circuit impedance
- Losses

USE

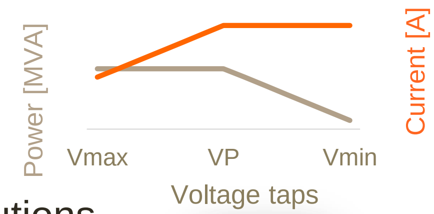
- Temperature control
- Working time management
- Load Management
- Conditions monitoring and control

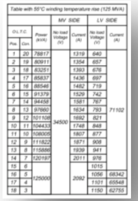
How to design a SMART Transformer

Secondary voltage range

- The designed internal power is related to the secondary voltage range:

$$P_d \propto \frac{P_n}{2}\left(\frac{V_{2\max}}{V_{2\min}} + \frac{V_{2\max}}{V_{2p}}\right)$$





- An unused range of voltage increase the designed power
- A wide range of voltage taps leads to expensive and improper design solutions

Number of taps

- An incorrect number of taps leads to:
  - Long time period for the transition through the secondary voltage range
  - Expensive tap changer solution or transformer schema solution

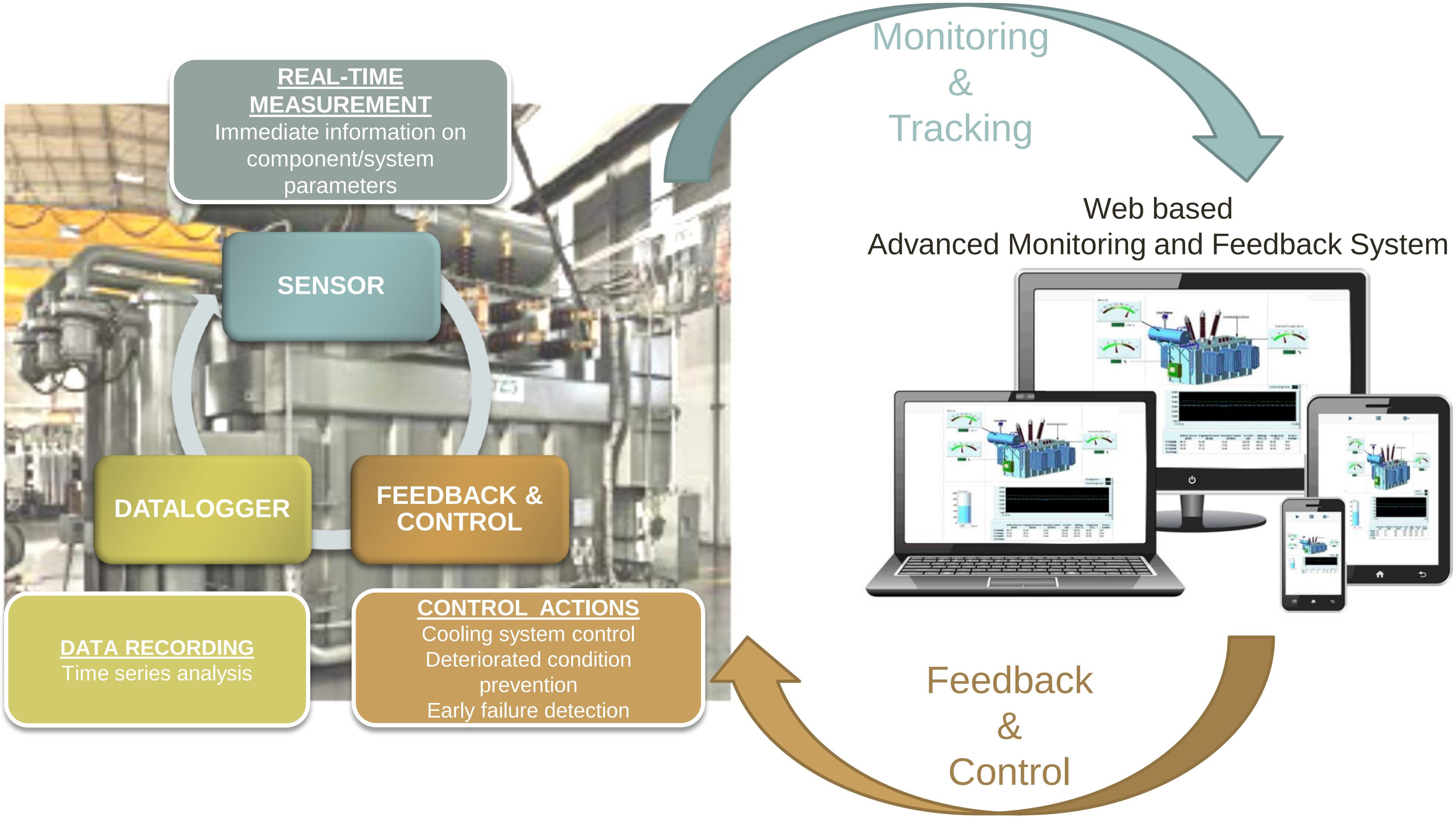
Short circuit impedance

- The variability of the short circuit impedance highly influences the design and the efficiency of the transformer

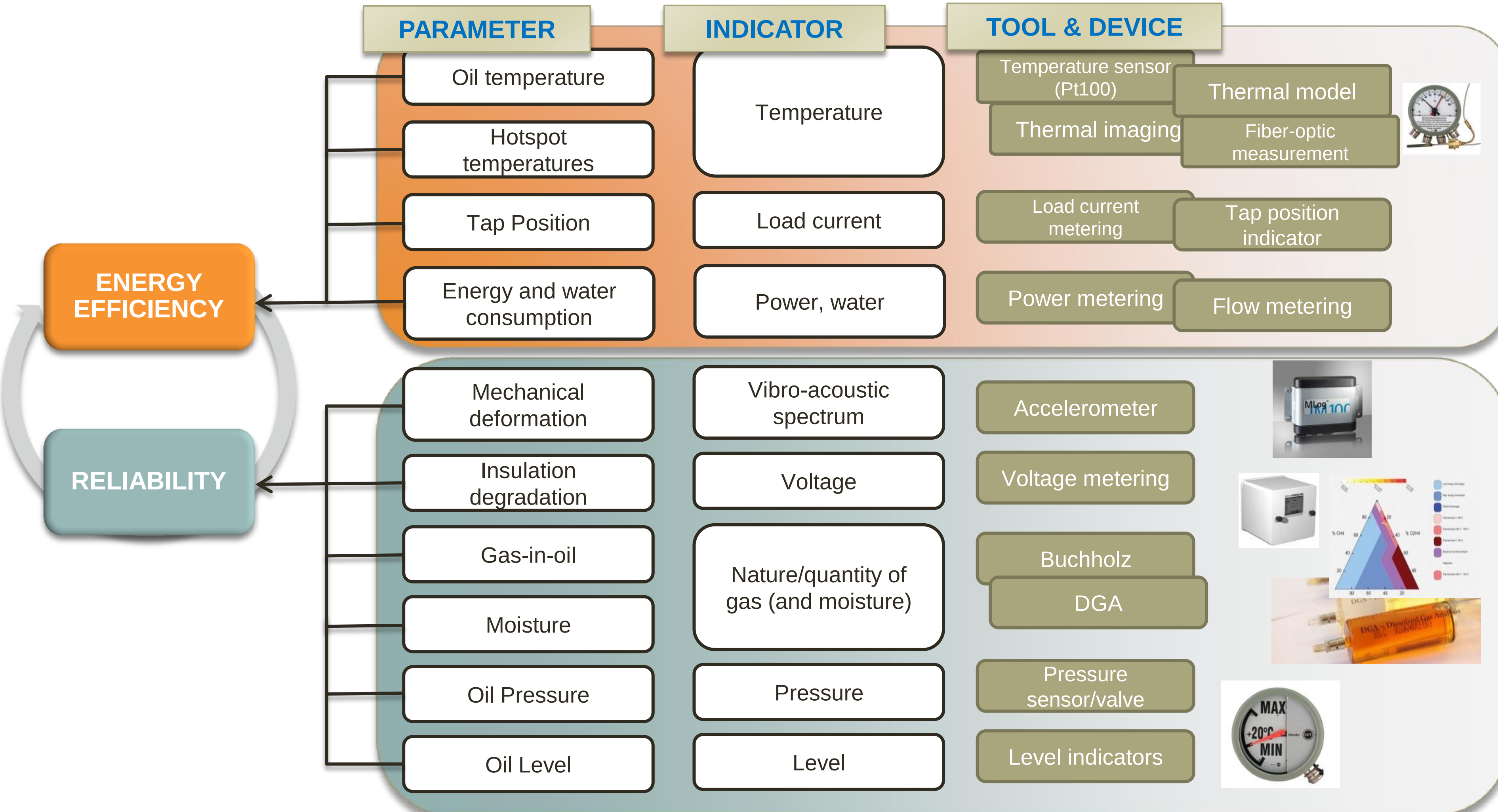
Losses

- The target losses should be carefully evaluated in terms of global efficiency, not only in terms of price reduction criteria
- Total losses should encompasses all the transformer and related elements losses
  - cooling system
  - low voltage terminations
  - auxiliary accessories
  - …

Monitoring & Control system



Parameters Effects



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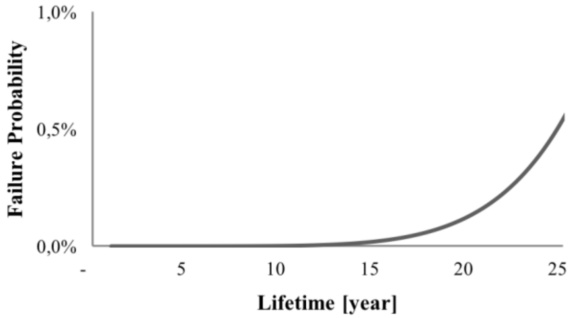
Numerical example

DATA

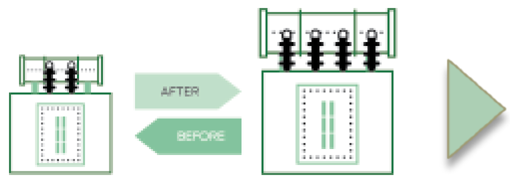
- Load Cycle: 45 min at 160 MVA, 15 min at 0 MVA
- 250 days a year x 20 years
- Transformer A: 140 MVA (+ 15% overload)
- Transformer B: 160 MVA
- OFWF cooling system: 2 x 75%
- Annual discount rate, r: 5%
- Electricity cost: 0.15 €/kWh
- Contribution margin: 100 €/ton
- Maintenance activities
  - 100 h per year of out-of-service
  - 50 k/year

		Transformer A	Transformer B
Rated power	[MVA]	140	160
Purchasing price	[k€]	1200	1500
No-load losses	[kW]	62	60
Load losses	[kW]	800	800
Cooling system cost	[k€]	29.54	21.02



Tailor made solution effects

	Existing Transformer at rated power	New Transformer at reduced power	Existing Transformer in overload	New Transformer at rated power
Power	140 MVA	140 MVA	160 MVA	160 MVA
Load losses	800 kW	600kW	1050 kW	800kW
No load losses	62 kW	60 kW	62 kW	60 kW
Total losses	**862 kW**	**660 kW**	**1112 kW**	**860 kW**



- 250 [kW]

New TES vs existing transformer for a cycle with 45 min at 160 MVA and off for 15 min : -**188 [kWh/cycle]**

		Transformer A 140 MVA	Transformer B 160 MVA
Life cycle cost	[k€]	15,541	12,806
Transformer price	[k€]	1200	1500
Losses cost	[k€]	13,296	10,364
Cooling system cost	[k€]	368.12	261.97
Maintenance cost	[k€]	677.15	679.76

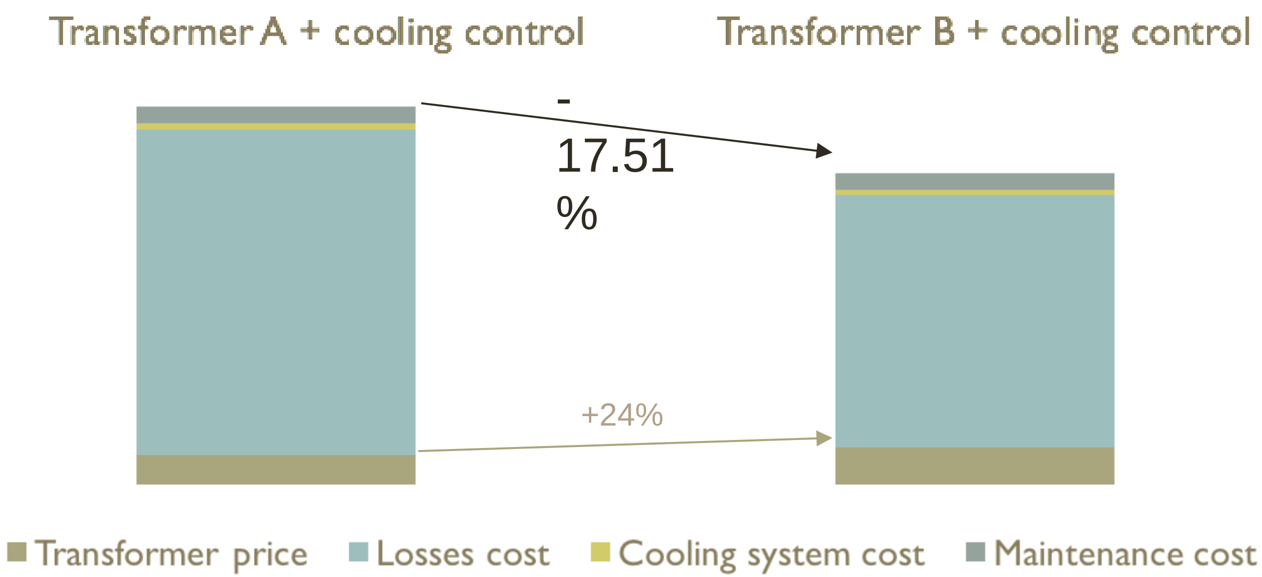
LCC reduction of 17.12%

Example: Cooling control effects

USE

Cooling system

		Transformer A 140 MVA	Transformer B 160 MVA
Life cycle cost	[k€]	15,490	12,778
Transformer price	[k€]	1230	1530
Losses cost	[k€]	13,296	10,364
Cooling system cost	[k€]	286.67	204.24
Maintenance cost	[k€]	677.15	679.76



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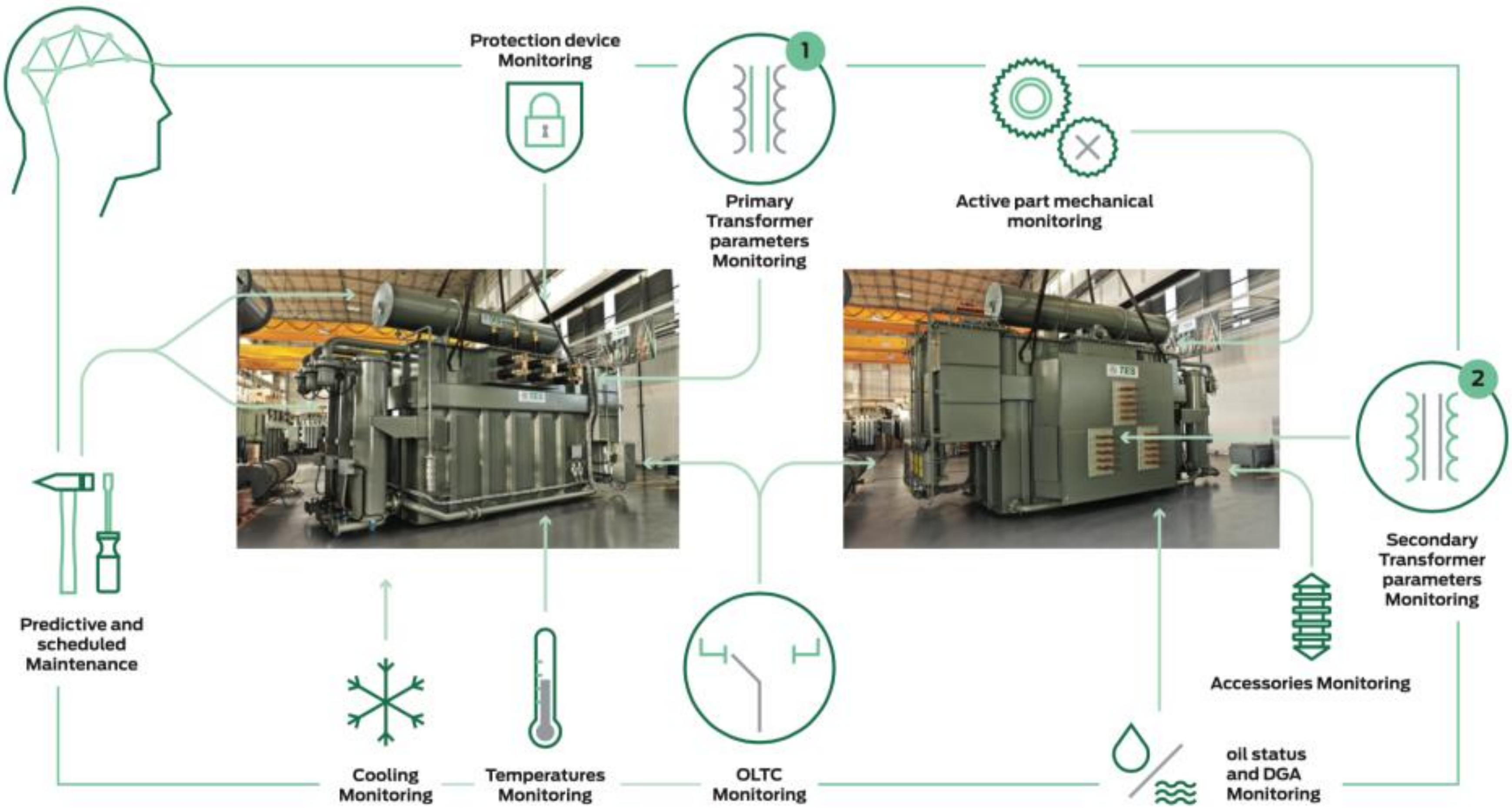
Conclusions

- The improvements performed in the last decades on the EAF do not reach the limit in terms of process efficiency
  - holistic approach considering all relevant components of the process
  - greater part of the melting energy passes through electric transformer
- LCC model on transformer already exist but none of them are specific for the EAF transformer
  - EAF transformers are exposed to specific and more critical conditions than power and distribution transformers, thus it is necessary to consider real operations conditions
- The present work proposed a new holistic LCC model to determine total ownership cost of EAF transformers
  - evaluation of a technological solution that best suits the system requirements to minimize electrical losses, incorporating the proper **design** of all components (i.e. on-load-tap changer, LV terminals, etc.);
  - integration specific costs associated with the **operation** and components configuration effect, using a feedback regulation systems incorporated in the process control system (i.e. regulations of pumps for the cooling system);
  - implementation of an advanced **monitoring and control system** for the transformer and its main components to improve its lifecycle and optimise planned maintenance ;
- A couple of numerical example showed the impact of the real conditions and operation on alternative solutions.

Conclusions



THANKS FOR YOUR KIND ATTENTION

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