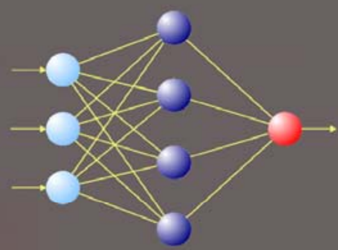
FERROTRON

A MINTEQ DIVISION



Optional Neural Power

DECTEQ™ "P-Melt+"

Melting Optimization and Automation Tools for AC Electric Arc Furnaces (EAF)

- The DECTEQ™ module "P-Melt+", solves the problem of the dynamical changing working points
- Intelligent controller, based on a neuronal network
- Self learning the melting behavior of the EAF during several heats
- Acts like an experienced operator
- Initiates automatically changing the transformer reactance
- Able to predict the panel temperatures to prevent hot spots, assumed that the temperatures of the panels are measured
- The "P-Melt+" module may increase the heating efficiency, decrease the maintenance and reduce operating costs

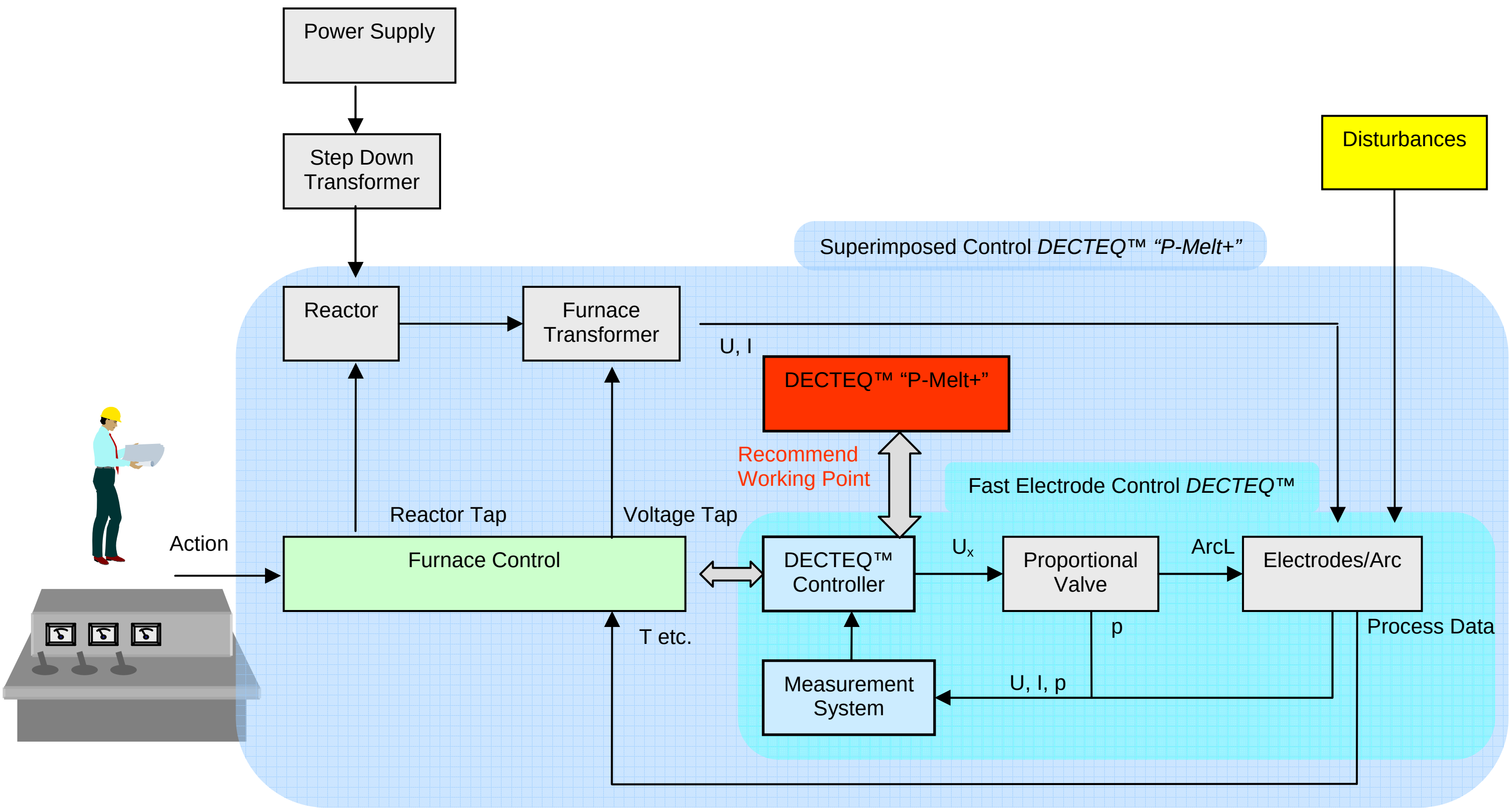
DECTEQ™ "P-Melt+"

DECTEQ™ "P-Melt+" is a **superimposed software controller** for the **basic electrode control DECTEQ™**. It contains a variety of tools, which can be used for the **optimization of the heating power** as well as for the **extended automation** of an electric arc furnace.

Usual electrode controllers use fixed reference values, which are taken from a 'short moment' of the time variant electric furnace diagram. This compromise leads to a deviation of the heating power between the different heating phases. DECTEQ™ "P-Melt+" updates the furnace diagram continuously and looks for the maximum of the arc active power for the actual transformer tap. Hereby, different secondary conditions, as the heat radiation of the arc, electrode consumption, furnace shell and roof temperatures, can be taken into account.

DECTEQ™ "P-Melt+" overtakes all important decisions of the operator and controls the heating process. There are defined melting strategies with secondary conditions, which have to be kept during the heating process. The most important **melting strategy** is to transfer the available electric energy into a maximum of thermal energy to reduce the heating time and to reduce the energy consumption. While these strategies are **long range** conditions, it is not necessary to implement a fast real time hardware controller as for the basic controller DECTEQ™, but it is sufficient to adapt the control parameters in long range cycle times by a software controller. Hereby the process data are exchanged between the DECTEQ™ "P-Melt+" and the DECTEQ™ application continuously.

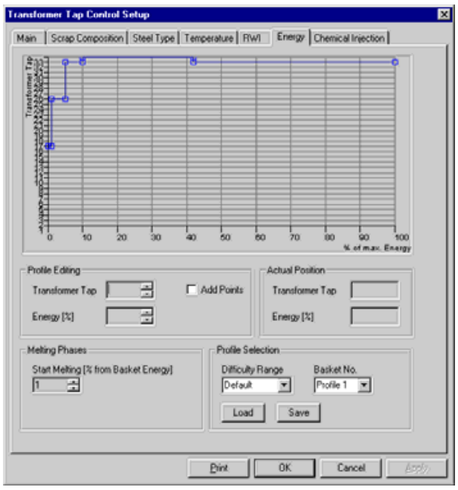
Beneath the **optimization of the heating power** it is possible to use DECTEQ™ "P-Melt+" just for the **automatic control of the transformer and reactor taps**. In this case the taps can be switched via defined switching profiles as a function of the melting progress. Furthermore the **controller gain** of the basic electrode controller DECTEQ™ can be adapted dynamically as a function of the heating behavior.



DECTEQ™
- Fast real-time controller with digital signal processor (DSP)
- Control of the reference value via electrode positioning

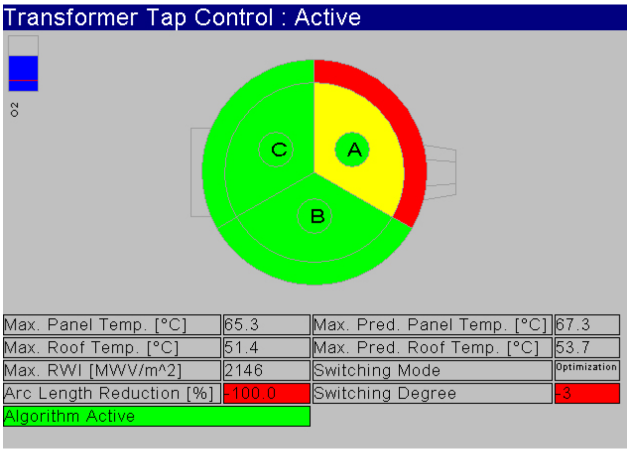
DECTEQ™ "P-Melt+"
- Superimposed software controller for the power optimization
- Automatic control of the transformer voltage taps
- Automatic control of the reactor taps
- Adaptation of the reference value to the melting process
- Adaptation of the controller dynamic to the melting process

The DECTEQ™ "P-Melt+" Modules



Control of the transformer tap

The transformer tap is typically switched as a function of the electric energy consumption, which corresponds to the **melting progress**. During the penetration phase the melting starts with a lower voltage tap and a reduced arc length to protect the furnace roof from being overheated by the arc. After the electrodes are immersed into the scrap and the arc is fully covered by the scrap, the voltage tap is increased. During the fining phase, when the steel is fully liquefied, the tap is decreased, dependent on the slag cover, to protect the furnace shell from being overheated by the arc. Especially during the fining phase, when the steel is fully liquefied and the arc is no more covered by the scrap, the shell may be overheated by the arc radiation.



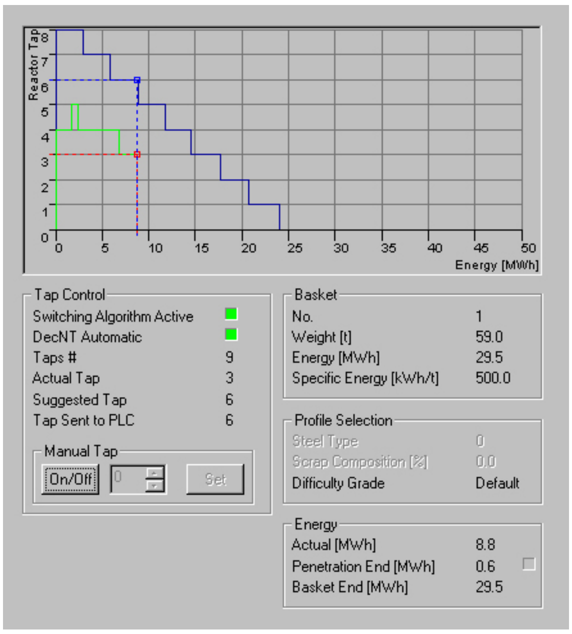
The aim is to run the Furnace close to its electrical and thermal limit

Voltage tap is dependent on...

- Shell temperatures by monitoring of the cooling water temperature as well as the use of a neural network for the prediction of temperatures
  - melting progress
  - calculated RWI
- Control of the load limits by early
  - changing of the set point
  - changing of the transformer tap

Automatic Reactor Tap Control

The module for the automatic reactor tap control can be used for the extended automation of the furnace system but also for the adaptation of the furnace reactance to the melting process. The tap control can be realized as a function of the electric energy consumption or loop controlled as a function of the harmonic content or the standard deviation of the electrode currents by use of a defined switching profile.



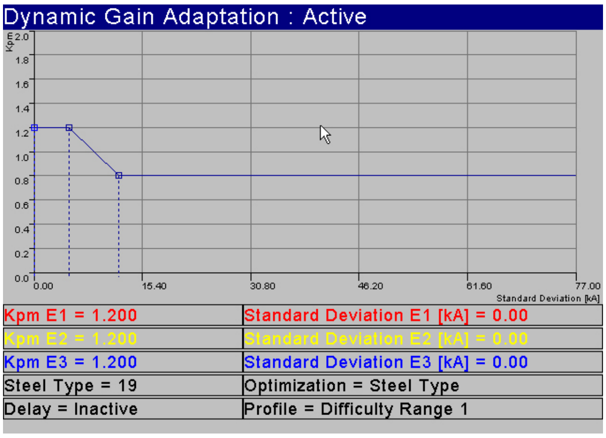
It is clear that the role of a reactor is a 'disturbance limiter' which reduces the heating power and increases the heating time, if the tap is selected too high or the tap is reduced too late. If the heating process is accompanied by a variety of parameter changes, e.g. steel quality, steel quantity or injection of additives, it is useful to adapt the reactor tap to the heating behaviour. The heating behaviour can be characterized by measuring the harmonic content or the standard deviation of the electrode currents.

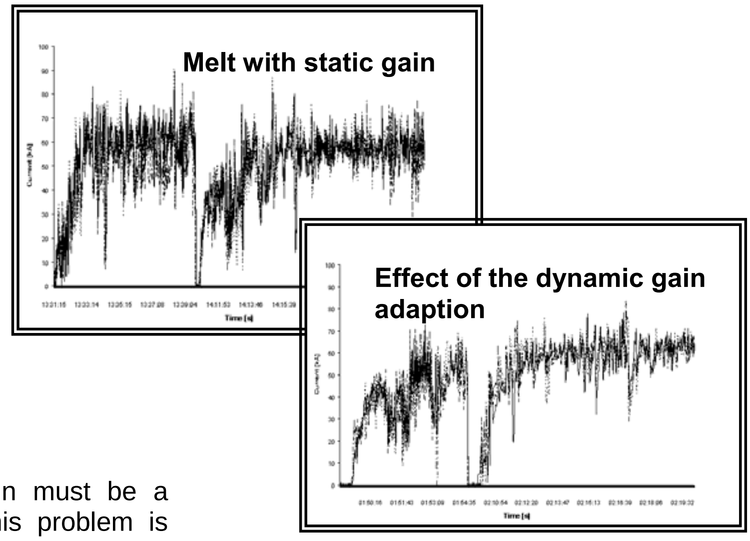
- Switching only in one direction
- Switching, if g_u-point is reached
- Switching at the latest, if MWh-point is reached

Switching of the reactor tap as a function of the electric energy consumption by use of a defined switching profile

Dynamic Adaptation of the Controller Gain

The module for the dynamic adaptation of the controller gain is used for the modification of the proportional factor of the basic controller DECTEQ™ as a function of the heating behaviour. The heating behaviour can be characterized by measuring the harmonic content or the standard deviation of the electrode currents.



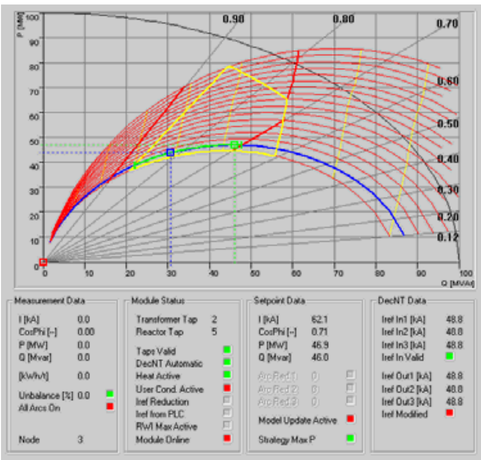


It is clear that the selection of a fixed controller gain must be a compromise between the different heating phases. This problem is solved by the modification of the controller gain as a function of the heating behaviour. The heating behaviour can be characterized by measuring the harmonic content or the standard deviation of the electrode currents.

- **Avoidance of higher current peaks**
- **Smoother melting behavior**
- **Reduction of load fluctuations**

Dynamic Adaptation of the Setpoint

The module for the dynamic adaptation of the set point is used for the optimization of the heating power with respect to the defined melting strategy and the thermal load of the furnace shell. This is realized by modification of the static reference currents, which are defined in the basic controller DECTEQ™, continuously in a specific update cycle time.



The most important **melting strategy** is to transfer the available electric energy into a maximum of thermal energy to reduce the heating time and to reduce the energy consumption. Therefore it is necessary to use an **electric model of the furnace system**, which should be exact as possible, to define the operation and control parameters. In the beginning of a melt the reactance of a furnace system is increased compared to the reactance, when the steel is fully liquefied. This effect is essentially based on the non linear electric behaviour of the arc and occurs especially during the penetration and main melting phase. The reactance is decreased with the melting progress and approaches to a stationary value after the steel is liquefied. This so called **operation reactance** is an essential basis for the electric modelling of a furnace system, from which the reference values for the electrode control are taken.
The adaptation of the electric furnace model is done by use of a neural network with respect to different **secondary conditions** as

Main Melting strategies:
- Maximum arc power **Pmax**
- Constant arc Power **Pconst**
- Constant reactive power **Qconst** for minimizing flicker
  Constant power factor **cosφ**

Secondary conditions:
- maximum allowed deviation of the maximum arc active power
- temperatures of the furnace shell
- radiation power of the arc (RWI)
- electrode consumption

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