Active Power Feeder, a Ground-breaking Power Solution for Feeding Electric Arc Furnaces

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Active Power Feeder (APF) is a modern power supply system specially designed for AC Electric Arc Furnaces (EAF). APF utilizes an electronic actuator, the Modular Multilevel Converter (MMC), to supply real power from the supplying medium voltage bus to the electric arc furnace in a very grid-friendly way. High power quality, i.e., low flicker, low harmonic distortion and excellent power factor are achieved. A compensation system is not required and additional power consumers on the bus are compensated. A ground-breaking dynamic process control increases the stability and efficiency of the furnace operation. Furnace current, frequency, and arc voltage are automatically adjusted according to the operational situation, to minimize the current fluctuation, avoid overcurrent and to increase the arc stability. The fast, stepless digital control maintains optimum furnace working points, reduces the power-on time and energy consumption. The strict limitation of overcurrent situations reduces the stress and wear for the electrical and mechanical furnace equipment and results in reduced maintenance and electrode consumption.

With APF, the conventional EAF becomes a digital green EAF.

1. Explanation of APF

Main features of APF, a new power supply for EAF are:

- To feed active power from the grid to the EAF.
- To support and stabilize the grid voltage and frequency.
- Digitally control the EAF melting process, i.e., highly dynamic and efficient.
- To deliver high energy efficiency, high productivity, stable operation, and high availability.
- To make additional compensation systems (SVC: Static Var Compensator, STATCOM: Static Synchronous Compensator etc.) unnecessary.
- To make electro-mechanical equipment, like reactors, tap-changers, furnace switches unnecessary.

The main advantage of APF is that EAF side and grid side are decoupled from each other, and each side is individually controlled by a fast and stepless digital actuator (**Figure 1**).

An MMC connected to the medium voltage level is preferred as electronic power supply, for its lower electrical losses, perfect voltage and current shapes with lowest harmonic distortion, fast and precise actuation, highest availability and installation flexibility.

The converter can be installed outside of the melt shop building at a convenient, economic location and has an optimal footprint (**Figure 2**). This is a significant advantage in plants with limited space and in modernization projects.

The APF converter controls the grid side and the EAF side independently:

- Control on grid side

With its Active Front End (AFE) the APF has full control of the power quality up to the PCC (point of common coupling) (Figure 2). The AFE maximizes the power factor toward the grid and eliminates harmonic distortions and flicker. An additional compensation system is not required.

- Control on EAF side

With its fast dynamic process control, the APF ensures a fast, smooth and safe melting process. In comparison with conventional EAF where the furnace can only be controlled slowly by electro-mechanical actuators like tap changer and electrode arm movements, APF's fast and stepless digital actuator can react instantly to process disturbances and can stabilize the operation.

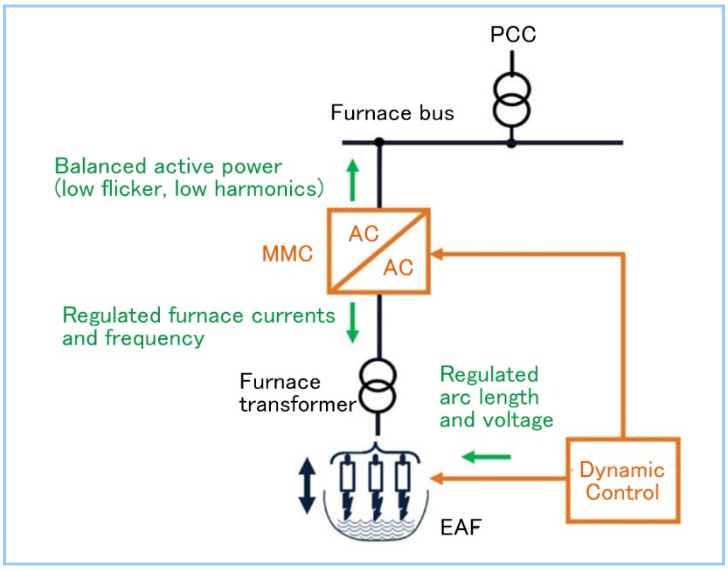

Figure 1 APF, a new power supply system for EAF

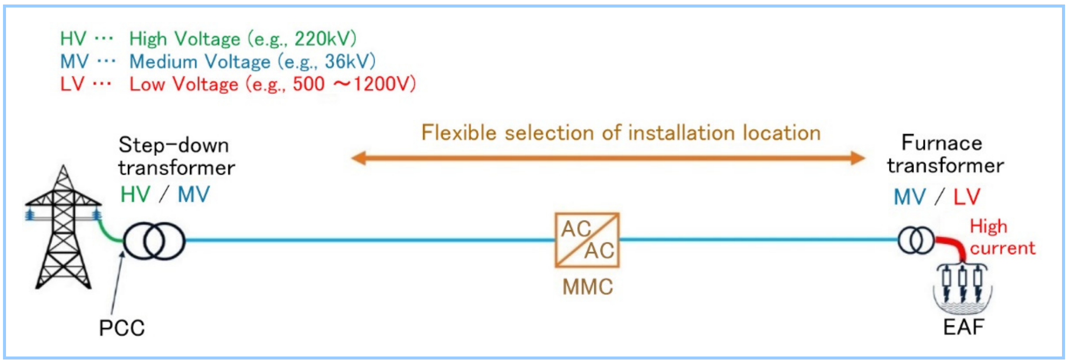

Figure 2 Installation flexibility with APF

2. Comparison with conventional technology

In comparison with conventional EAF where the furnace is directly attached to the furnace bus, the MMC of the APF is connected in between the furnace and the furnace bus (**Figure 3**).

Due to the violent melting process of scrap, the conventional electric arc furnace as electrical load is very unstable (**Figure 4**). The dynamic behavior of the arc inevitably leads to strong perturbations in the current like loss of arc, short circuit, load fluctuation and unbalance. Finally, this causes high flicker, high harmonic distortion and poor power factor.

The perturbations are significantly faster than the control speed of the electro-mechanical positioning system of the electrodes and actuations with the on-load tap changer of the furnace transformer. To comply with the grid code requirements, additional compensation systems such as SVC or STATCOM are mandatory to minimize network perturbations and maintain a high power factor.

In comparison APF does not require additional compensation systems and filters. Still the compensation capability of APF is significantly better than a STATCOM with filters. With APF a very high flicker reduction factor better than 10 can be achieved. The dirty furnace bus becomes a clean bus and an additional ladle furnace can be compensated without additional compensation equipment.

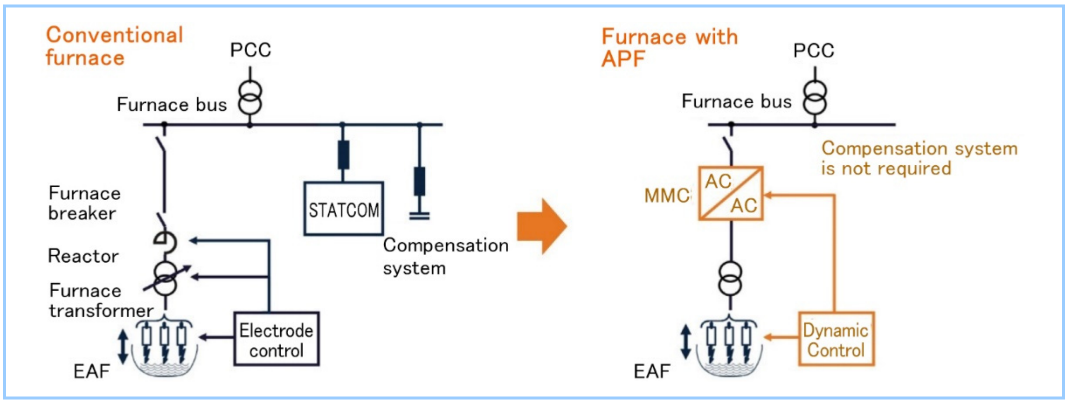

Figure 3 Transition to digital Green EAF with APF

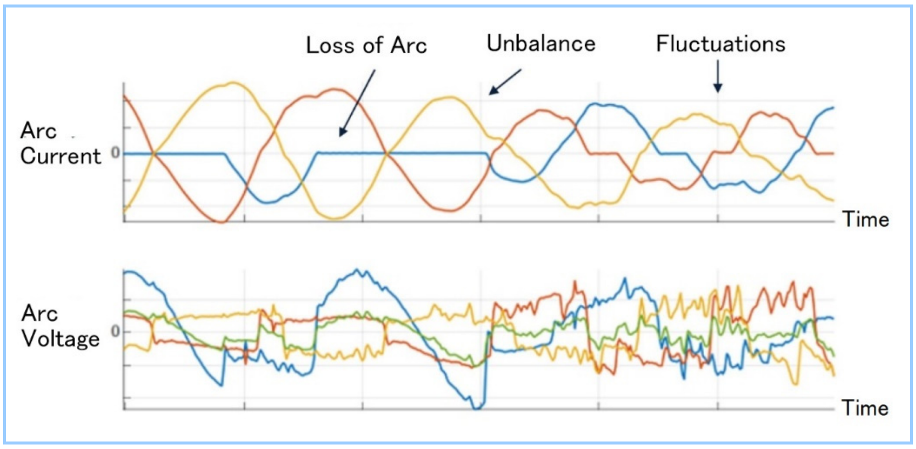

Figure 4 Power quality issues caused by EAF operation (example)

3. New dynamic process control

The MMC is the new fast, stepless actuator for high dynamic digital furnace control. Setpoints are provided by the electrode control, the Melt Expert.

Current and frequency are actuated by the converter. Arc length (arc voltage) is actuated by the electrode arm hydraulic system.

Each electrical phase is actuated individually to control hot or cold spot.

Steel grade-related power recipes are stored in meltdown profiles and are activated according to the melt down process condition, i.e., boring phase, melt down phase, flat bath phase.

The main control activities are realized by the fast and stepless current control of the converter and preferably at a fixed transformer tap. The movements of the hydraulic system and herewith the electrodes are minimized and mainly follow the scrap melt down.

4. Improvement and saving potential by the regulated furnace currents

Regulated furnace currents are the basis for increasing the active power input into the furnace and finally to decrease the power-on time and increase the furnace productivity. The simulation in **Figure 5** compares the furnace currents in conventional operation (blue color) with APF operation (red color) for a two-basket melting.

The dynamic process control minimizes process disturbances during boring/melting phase very efficiently and we observe significantly reduced current fluctuations, increased arc stability and a strict limitation of over current situations. This makes operation safer and allows to increase the active power input into the furnace, especially during boring and melting phase. The simulation in **Figure 6** shows the positive impact on the power-on time which can be reduced by -10% in this example.

Energy saving in the boring and melting phase result from the shortened power-on time, i.e., from reduced heat losses and from reduced electrical losses. In the example this corresponds to reduced electrical energy consumption per ton of produced steel of -8%. In the case of stable arcing, additional savings in the melting phase, flat bath phase are possible by a decreased operation frequency with reduced electrical losses, e.g., 40 Hz instead of 60 Hz.

The reduced current fluctuation result in additional savings in the operation cost like reduced electrode tip consumption (-5% in Figure 6), reduced electrode breakages. The electrical and mechanical stress in the equipment is significantly reduced, resulting in a smoother operation with higher availability of the furnace and reduced maintenance cost for existing furnace transformer, on-load-tap-changer, furnace breaker, flexibles, electrode arms.

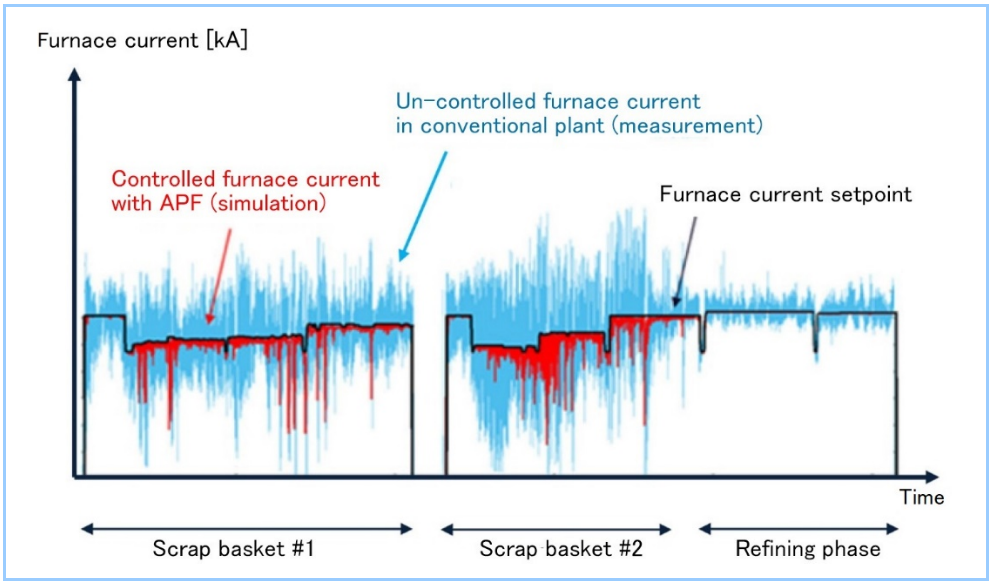

Figure 5 Regulated furnace current with APF

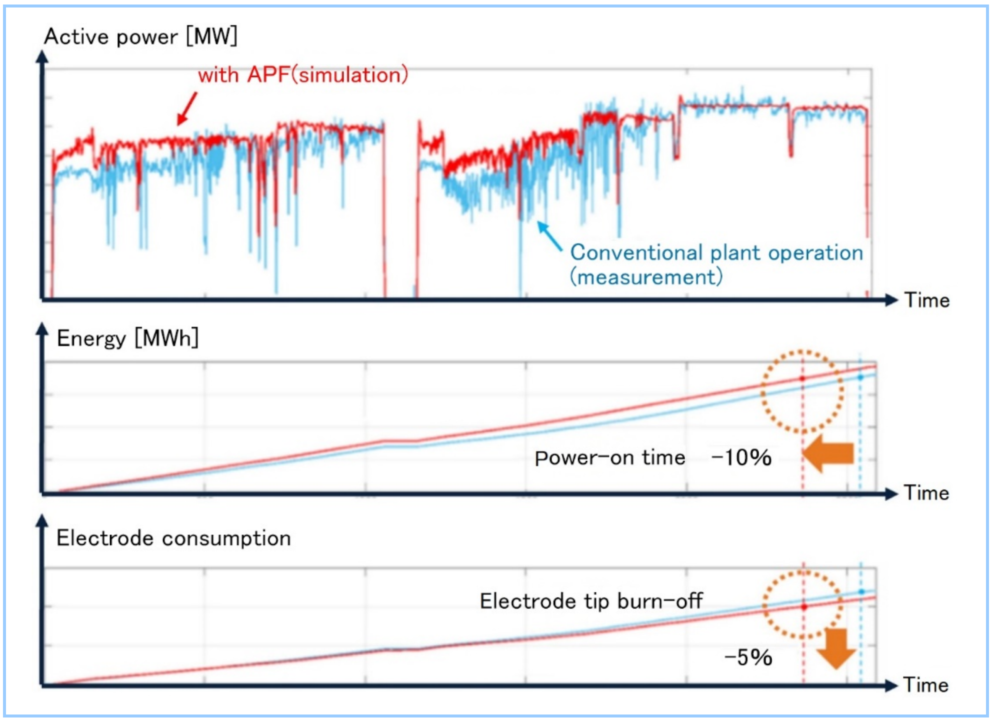

Figure 6 Increased active power input, reduced power-on time and reduced electrode consumption with APF

5. Future prospects

APF will be installed in a 50-ton electric arc furnace in Germany in 2025 to demonstrate the environmental, technical, and commercial benefits of the new technology. The furnace will be powered by an APF featuring a 3-phase indirect MMC. APF is well suited to power a wide range of AC furnaces, including scrap- and DRI-based furnaces. Capacity wise large furnaces up to 300 tons and higher are on the APF roadmap.