Optimization potentials of DC arc furnace regulating systems

Many DC arc furnaces have been operating since their commissioning without modifying or optimizing the regulating system. Usually the regulating system was given a highly dampened adjustment during commissioning to avoid problems. This is where the great potential of the old installations lies. Through advanced technology it is possible to upgrade hard and software to improve the regulating behaviour. This paper presents the implementation and results of selected regulator modernization and optimization projects.

Dipl.-Ing. (FH) Dirk Riedinger, Electrical Engineering Consulting Steel Plants and Rolling Mills; Dipl.-Ing. (FH) Hans-Peter Pfaff, Control and Automation, **Badische Stahl Engineering GmbH**, Kehl, Germany

Contact: www.bse-kehl.de
E-mail: dirk.riedinger@bse-kehl.de

During the 1990s many DC arc furnaces were built worldwide, because they were considered to have significant advantages over AC arc furnaces, e.g. only one electrode, current regulation with less disturbances on the supply network, etc.

Nowadays practically no more new DC arc furnaces are built, probably due to the reason that the assumed advantages were small when taking into consideration the overall balance (consumptions, productivity, technology). Another reason is that, after the demand for this technology had ceased, the suppliers discontinued the departments dedicated to DC arc furnace engineering. As a consequence experienced personnel and the know-how to build DC furnaces is no longer readily available. Thus also the service for existing installations is difficult to obtain. Nevertheless the situation is improving due to the present boom in the steel industry.

In many cases the DC arc furnaces still feature their original rectifier and electrode regulating systems. These systems have, however, some disadvantages. Firstly, they are often a black box. The responsible engineers have no access to important parameters or setpoints. This is amazing because complex systems such as rectifier and electrode regulation of an arc furnace should be fully accessible and tunable.

Secondly, the knowledge about the systems is limited. The management often does not consider modifications because the potentials are not known or improvements do not seem to provide enough benefits. So the systems are not touched ("Never touch a running system").

Thirdly, the electronics and programming of the regulating systems are obsolete and difficult to handle compared to today's technology.

As a result the power input is low and the power-on time is longer than necessary. This situation can be changed by an investment which is small compared to the achievable benefits in terms of increased production output.

Optimization procedure

The optimization of such installations requires considerable expertise. The original supplier must be contacted for upgrading the hard and/or software of the regulating system ("chip tuning"). Technical experts are still available for such modernizations. The development has not stopped either. Hard and software has been improved (mainly for other rectifier systems which are based on the same technology).

The technical experts often only have a limited know-how of the arc furnace process. Therefore it is necessary to have an arc furnace process expert involved in the optimization project. In cooperation with the customer he does the assessment of the operating and regulating behaviour and advises the technical expert on how to set up the regulating parameters and the power profile (setpoints) to achieve optimal performance. In this way special technical know-how linked with process know-how will provide the optimal benefit.

But how does the optimization or modification look like? If the regulation hardware is to be retained, the first step is to open the black box, i.e. to make the internal parameters of the regulating system and setpoints accessible. Then, if appropriate, an upgrade can be installed during a regular downtime, followed by parameter tuning during normal operation.

The optimization concentrates on the following main regulation parameters:

- gain of the voltage and current PI regulator (K_p values),
- integration time of the voltage and current PI regulator (T_i values),
- output signal of voltage regulator for up and down-speed of the electrode,
- certain limits and adaptive parameters.

A very important parameter is the movement of the electrode. It must be dynamical enough to keep the desired setpoint and regulate short circuit and arc extinguishing (current drops). This is where ususally the highest potential is found as the electrode movements are damped too much (a properly working hydraulic system is obligatory). Sometimes also the current regulator is too slow. It can be speeded up to regulate deviations more dynamically.

Results

For assessing and optimizing the regulating performance, a tool is required which makes the electrical parameters of the melting process visible. Badische Stahl Engineering (BSE) uses an own development, the so called "DC Online Monitor" measuring system. It displays the characteristic diagram **(see figures)** of the DC arc furnace containing all information needed for assessment (i.e. shape and position of the measured point clouds compared to setpoints and limits) and provides an evaluation tool. In principle only the DC voltage and the DC current are required as input signals. These signals are available at every DC arc furnace and are easily accessible. It is surprising that this system is not a standard visualization tool used in DC arc furnace operation.

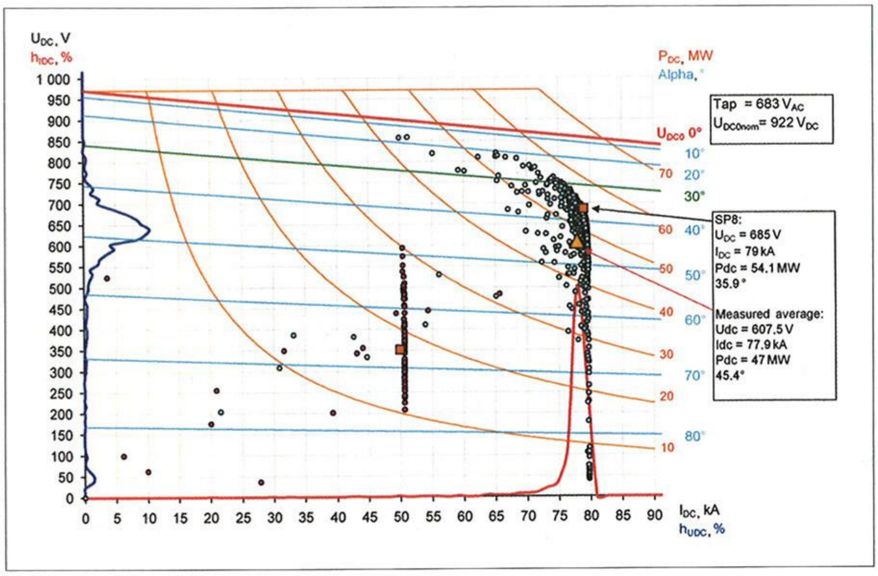

Figure 1. **EAF (1) regulating performance before optimization**

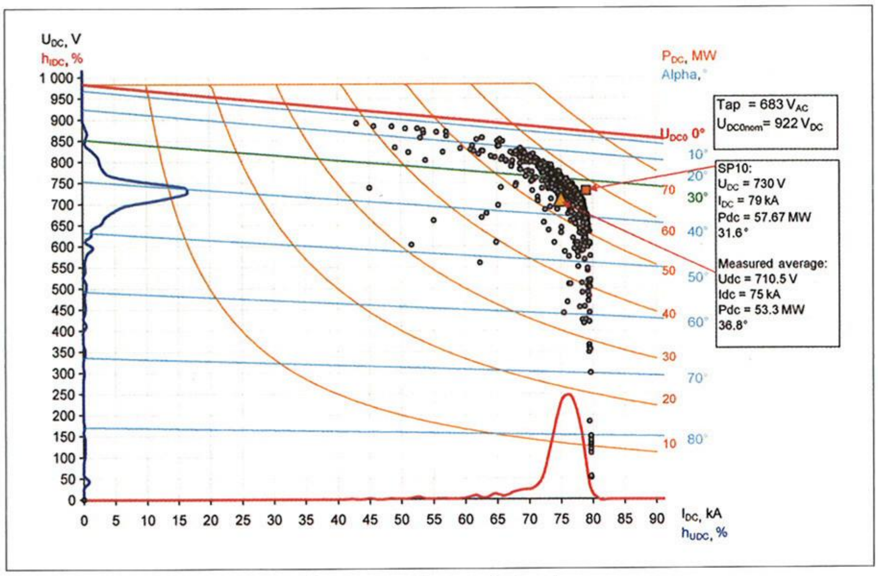

Figure 2. **EAF (1) regulating performance after optimization**

Example 1. This project was a pure parameter optimization campaign. The goal was to get access to the parameters and tune the regulation which used to be a total black box. The 78 MVA / 80kA DC arc furnace is equipped with a regulating system from Ansaldo Sistemi Industriali (ASI), installed in the 1990s. During a regular downtime ASI experts "opened" the black box for permanent access by installing programming software on a notebook computer of the customer. Then parameter tuning started. The melting process was observed by means of the DC Online Monitor system and the settings of the voltage regulator were optimized.

The main problems the system showed before the optimization were large negative setpoint deviations of the DC voltage, long short circuit durations of up to 20 seconds and very slow electrode movements. These conditions became obvious at a glance by the DC Online Monitor.

The adjustment procedure was as follows: the BSE process expert advised the ASI technical expert how to set the parameters and setpoints by assessing the operational behaviour with the DC Online Monitor. During two days the parameters were optimized empirically step by step in close cooperation with the customer.

Unfortunately the parameters of the rectifier PI regulator were still not accessible. The reason was the obsolete electronic hardware programmed in "cryptic" machine code. The results of the voltage regulator optimization can be seen in the characteristic diagrams **(figures 1 and 2)**. The active power input was increased by about 6 MW for the main scrap melting period. This was possible because a higher DC voltage setpoint could be used due to improved regulating dynamics. A lasting increase in productivity was achieved.

More benefits can be expected by a hardware upgrade with fast and modern electronics which are easily accessible and programmable. This would also improve the DC current regulation which is still not optimal (broad distribution, setpoint deviations).

Example 2. The goal of another project was to upgrade the regulation software, obtain permanent access to the parameters and then tune the regulation. The 90 MVA/110 kA DC arc furnace is equipped with an ABB regulating system which was installed in

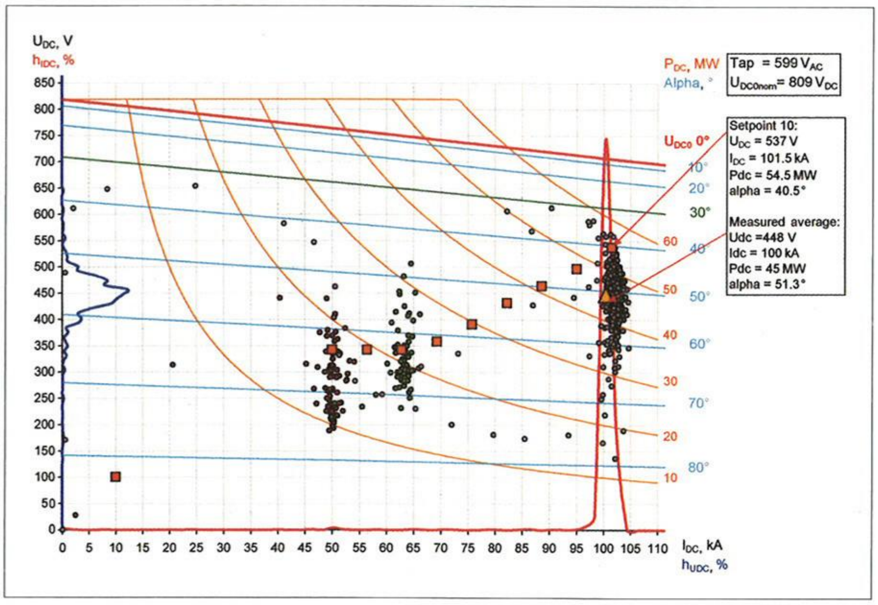

Figure 3. EAF (2) regulating performance before optimization

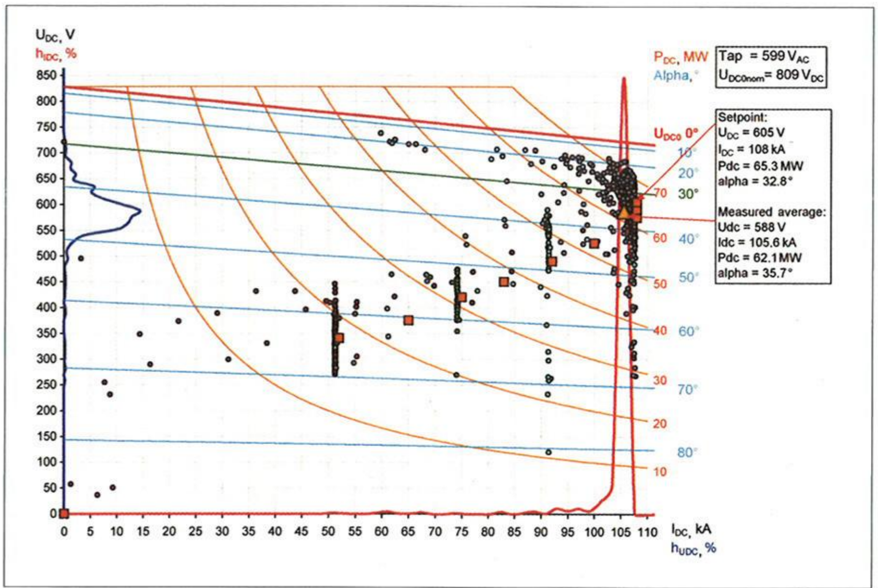

Figure 4. EAF (2) regulating performance after optimization

1993. This installation was a black box as well. No access was possible, the reason being that simply no programming device was supplied when the plant was commissioned.

The system was opened by an ABB expert using a regular downtime of eight hours during a five day optimization campaign. The software upgrade was installed and provided enhanced regulating performance. The hardware was old but still in a very good condition and working properly. The furnace HMI was extended for easy access of the setpoint tables.

The optimization was implemented in the same way as in example 1. The BSE expert advised the ABB expert on how to modify the parameters by assessing the arc furnace operation with the DC Online Monitor. At the same time the new regulating software allowed the use of higher DC voltages and currents, enabling tuning of the power profile (setpoint tables).

The results of the voltage and current regulator optimization are clearly visible in the diagrams in **figures 3 and 4**: less current fluctuation and less voltage setpoint deviation. The potential inherent in this 86 t furnace was large as the following values clearly indicate: the active power input was increased by more than 6 MW (50,6 to 56,9 MW) and the power-on time was decreased by nearly 3 minutes (39 to 36,3 min) on average per heat (two reference periods compared).

Such a power boost is not achievable for free. It leads to the "Formula 1 effect" which is an unavoidable increase in electrical energy consumption due to increased specific losses. In this case the specific electrical energy increased by approx. 19 kWh/t (other furnace parameters were unchanged). Measures to reduce electrical energy consumption are:

- avoidance of overmelting of the first basket,
- use of long arcs for scrap melting,
- operation at the lowest possible tapping temperature with only small deviations,
- use of a standardized scrap mix,
- switching off of the furnace during power demand limitations,
- reduction of the power-off times (setup and delay),
- efficient chemical energy input (door and sidewall).

Conclusion

These two exemplary projects clearly show the large potentials hidden in many DC arc furnace regulating systems. The investment in an optimization week and upgrades is very small compared to the benefits provided by such a campaign. Not only is the furnace operation improved, but also the maintenance personnel are trained and receive tools that enable them to deal with the system and take care of optimizing the melting process themselves in the future. In fact this must be the goal for every steel plant. The maintenance personnel must be able to optimize the furnace regulating system to always get the best performance out of it. The regulation must be adapted to the process, not the process to the regulation. The full benefit of an optimization project is achieved when a technical expert advised by a process expert form an experienced team. ■