Energy optimization in ESP with advanced control system

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In ESP intermittent energization, also called Semipulse, helps in optimizing ESP performance under back corona situations. [2-6]. Semipulse replaced the earlier method that just employed a reduction of the thyristor firing angle.

As a reduction of firing angle not only reduces the average current, but also reduces the collection area reached by the charged particles, the semi-pulse method was invented and realized once micro-processor controlled thyristors came to use for electrostatic precipitators.

As per existing method, the Semipulse energization is achieved by allowing power input of one semicycle and then blocking next one or more full cycles.

This paper will cover an advanced intermittent energization method developed for GE's latest 50/60 Hz High Voltage generation control system.

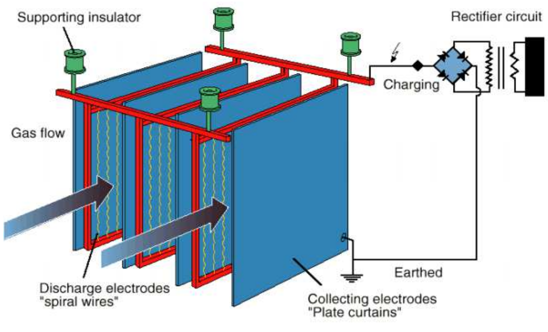

Figure 1. Basic ESP circuit

With 1:1 charging ratio (CR), no waveform is blocked. With this CR, 100% of the pulses is fed to the ESP (average current controlled by the ignition angle). For 1:3 charging ratio, one half wave form is fed and the next full cycle is blocked; for 1:5 CR, one half waveforms fed and next two cycles are blocked and so on. It means power can be fed into ESP in steps of 100%, 33.33%, 20%, 14.92%.... and if the need is to have power between these values, the only way to fine-tune is by a slight adjustment of the thyristor firing angle.

The limitation of not being able to use any other charging ratios (e.g. 1:1.5, 2:3, 1:4) comes from the fact that there is a risk that a Transformer Rectifier (TR) gets saturated if multiple consecutive pulses of same polarity (positive or negative) are fed.

The new Semipulse method by using Pulse ratio will avoid higher power consumption than needed for a certain emission level and make precise power control for back-corona possible at full- or ideal pulse current.

Charging ratio

Traditionally, pulsing has been determined by charging ratio. CR = 1:1 means that every pulse is fired. When 1:3, every third pulse is fired, CR 1:5 that every fifth pulse is fired etc. The denomination is always odd. An even number would cause T/R saturation by only firing one of the thyristors continuously.

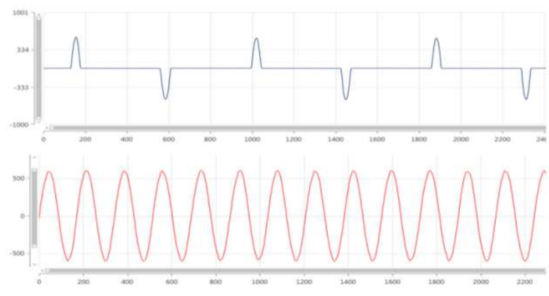

Figure 2. Triggered scope running at 20% Pulse ratio (CR 1:5)

Pulse ratio

In the new advanced control algorithm, the possible ways of applying pulses to the SCRs are extended compared to CR that is used in its predecessors. By eliminating pairs of pulses, a pulse pattern with more precise control can be achieved where saturation of the T/R is still avoided. Using the patterns, you open up for use of smaller steps in energy control.

Energy Optimization

Why optimizing energy? The main goal for saving energy in an environmental device is to reduce total environmental load (reduce emission of carbon dioxide, transportation of fuel and so on), for some plants there are economic gains as well.

E.g. an ESP typically using 1 MW, and the energy optimization algorithm saves 50% of the energy (a realistic value) 500 kW can be saved. The 500 kW reduction can be transformed into to 0,5 ton coal per hour which corresponds to ~2 tons of CO2 per hour.

If this amount of CO_2 would have been captured, with a modern carbon capture system it would have cost the power plant ~700 k€ annually.

The energy optimization algorithm used by the new ESP control algorithm from GE uses the new Pulse ratio philosophy to reduce energy. This allows the peak voltage to be high but the pulses will be less frequent and therefore save energy. The figure below shows when the control algorithm is set to run at 93% Pulse ratio, saving 7% of energy but with the peak voltage and corona pulse current still high.

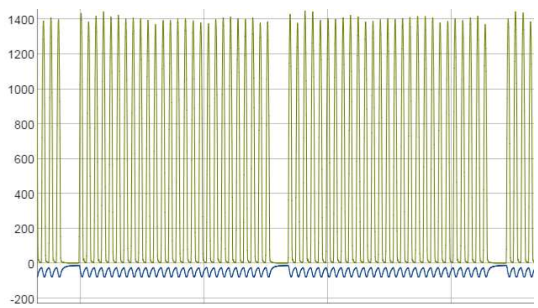

Figure 3. Scope capture Secondary voltage (blue) Secondary current (green). The scope trace is captured by the internal controller oscilloscope function

The figure below also shows a power saving of 7% but this time it uses idle current of 17.7% and a Pulse ratio of 91.5%. This can be used to keep the voltage level higher during the idle pulses to keep the corona active.

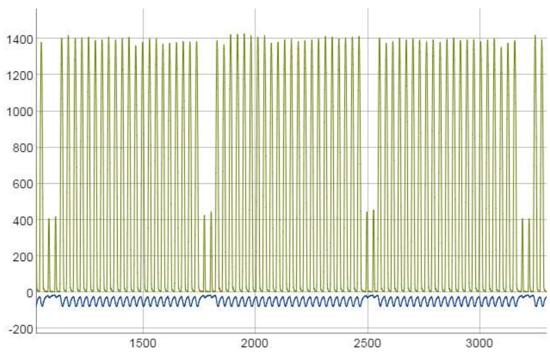

Figure 4. Scope capture Secondary voltage, Secondary current. The scope is captured with the internal controller oscilloscope

Q is a value calculated to determine the optimum energization.

The Q value is calculated by the formula [1]:

$$Q = f(u, u_{ref}) \qquad (1)$$

Where u is the secondary voltage; u_{ref} is the corona onset voltage; N is number of samples in one pulse cycle. Q is the "tool" to estimate the optimum Pulse ratio and current, at any given situation.

Initial tests in lab show an indication that lowering the power consumption by pulse ratio versus the traditional way of only lowering pulse current, gives better removal efficiency with the same power consumption. This could also be used to keep the same emission and reduce power. Using Pulse ratio to reduce power gives about 20% reduction in energy compared to pulse current reduction. This was estimated using Q value calculations. see figure 5. These initial tests will also be performed in field pilot tests, and also later in full-scale field tests.

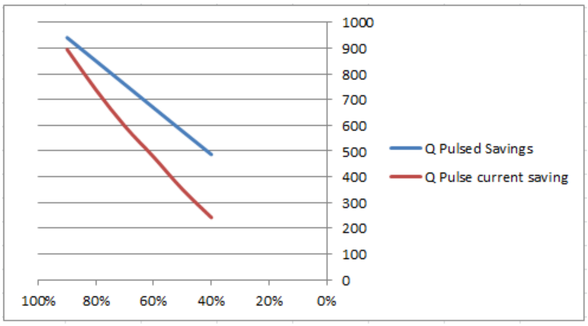

Figure 5. Measured Q value vs Pulsed power saving. Y axis shows the Q value, X axis shows the savings (from 90% to 40%)

To further reduce the power consumption the energy optimization algorithm uses a method of distributing the power to the fields where it contributes most to lower emission, see Figure 6.

Combining these two methods the power consumption can be reduced without losing cleaning efficiency. The EOPT algorithm takes the resistivity and filter layout into account when making these decisions. Typical values for an optimization can be 40% saved in the first fields, 90% in the intermediate fields and about 40% in the exit fields. See Figure 6.

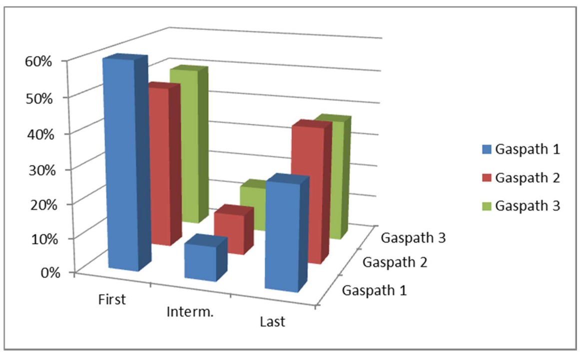

Figure 6. Energy saving in different fields. Varying the energy saving between the fields to get the optimum removal efficiency vs. energy savings

Back corona

Semipulse is proven to have a good effect on back corona situations. In previous GE ESP High-Voltage controllers, the highest possible power using pulsing was 1:3 (33.3%). This Pulse ratio may be a too big reduction from 100% Pulse ratio in some situations.

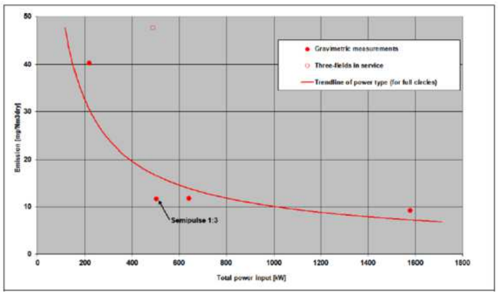

Figure 7. Emission vs. Power

The trend line shows 100% Pulse ratio. The marked 1:3 shows that we can get a lower emission running intermittent pulsing mode. This is especially significant in low resistive conditions.

With the new Pulse ratio philosophy the increments can be made smaller which opens up for a better optimization when the back corona effect is little. The new control algorithm uses the EPOQ feature to automatically adjust the settings Semipulse and corona pulse current density.

Combined

Energy Optimization (EOPT) and Back corona optimization (EPOQ) can be used at the same time to make use of the optimal Pulse ratio while keeping track of the stack emission limits. The example below shows when the EPOQ has chosen 33.33% Pulse ratio as the best performing setting from a back-corona point of view and then the current is further reduced it by EOPT to 25% when adjusting for the stack emission limit.

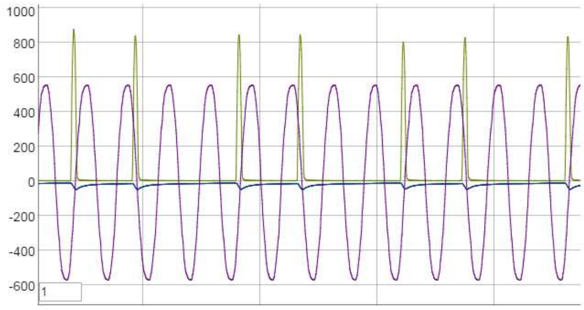

Figure 8. 25% pulse ratio. Scope capture Secondary voltage (blue) Secondary current (green) Primary voltage (purple)

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