Restoring efficiency, removing sound

Ready for DC in the grid with Siemens DC compensation and DC-ready transformers

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Challenge

Power grid operators are required to constantly maintain and improve efficiency of their grid and power equipment. At the same time, growing public awareness and urbanization requires minimization of noise pollution to the surrounding environment and neighborhood. As a consequence, power grid operators are continually specifying lower values of noise pressure and electrical losses for power transformers.

While these values are properly tested during the factory acceptance tests in a controlled environment, the actual situation in the grid may vary, for example due to impacts of Direct Current (DC). DC occurs from power electronics in the grid, HVDC interconnections, renewable power generation, or small direct currents caused by geomagnetic effects.

Solution

Siemens offers a 4-step approach to cope with the DC effects.

**Benefit DC detection**
- Quick and easy first indication of DC effects (snapshot)
- Proper indication of required next step

**Benefit DC ready**
- Future-proven design with state-of-the-art compensation hardware embedded
- No additional built-in hardware needed if DC needs to be compensated in the future

**Benefit DC measurement**
- Transparency about the dimensions of DC effects in the grid over some weeks
- Determine appropriate compensation power

**Benefit DC compensation**
- Set back noise and loss levels to nominal values
- Compliance to local regulations regarding noise pollution
- Reduction of costs for no-load losses
- Save additional noise enclosure

1. **DC detection**
   - Giving a first real-time indication of DC effects
   - The easy-to-use app transforms any smartphone into a DC detection device and can be used by any person at the site. The app records the noise level for all kind of transformers, independent of manufacturer. It processes the audio data, and visualizes any DC noise effects directly on the smartphone offline in real-time. A detailed report including recommendations can be requested directly from the Siemens experts by submitting the data online.

2. **DC ready**
   - Preparing transformers to be ready for DC measurement and compensation
   - The DC-ready design enables the subsequent DC measurement and DC compensation. The active parts of these transformers are already equipped with all required components, like compensation windings, internal measurement sensors, and connections. These components will be used for DC measurement (step 3) or DC compensation (step 4).

3. **DC measurement**
   - Solid determination and proof of DC level in the asset
   - The measurement device is connected to the DC-ready system. It determines the actual DC level. The measurement device connects to the DC-ready components installed inside the transformer and analyses the DC effects continuously over several weeks.

4. **DC compensation**
   - Eliminated DC in the asset and reduction of no-load loss and noise impacts
   - The compensation device is connected to the DC-ready system. It constantly analyses the DC effect on the transformer and generates the necessary direct current needed for compensation. The compensation windings installed in the DC-ready design are generating a magnetic field in the core to counteract the field produced by DC current. The required DC current is determined by sensors at the active part and controlled by a control unit. The DC effects on transformer noise and loss level can be nearly completely eliminated.
Technical Details

DC impacts are significantly increasing noise and loss levels. For instance, only a few hundred milliamperes of DC can already result in a significant increase of noise and no-load losses. A DC of 500 mA may cause an increase of 13 dB(A) compared to a reference measurement in the test field without DC. For a human being, an increase of 10 dB is perceived as doubling the noise. Furthermore, DC load causes an up to 50 percent increase in no-load losses.

Due to the magnetic conductivity of transformer cores, even a small DC impact can have major effects, including an increased reactive power current requirement, and associated greater losses.

Given a lifetime of minimum 25 years, power equipment needs to be already prepared today to cope with challenges by DC impacts in the future. With exponentially increasing renewable power generation, and thus a changing grid topology, the objective was therefore to develop a method to render the transformer insensitive to DC loads. Siemens is capable of distributing DCC preparation in a new transformer, which we call “DC ready.” This enables quick retrofitting to a full DCC system at a later stage.

Solution

The approach developed by Siemens Transformers is not based on eliminating the DC load, but rather on eliminating its effects on the transformer. The DC is therefore able to flow at a certain location and will not be obstructed. Siemens solutions for DC compensation for single-phase and three-phase units with three-leg cores as well as five-leg cores have been available since 2011. Our reference projects can be found all over the world, including Europe, Northern America, Africa, and Australia. In the future, we expect an increase of DC especially in Northern America, Europe, and the Asia-Pacific region.

Noise reduction with DC compensation

The concept of DC compensation in Siemens Transformers is not based on preventing the flow of DC current through the transformer, but rather on generating a magnetic field in the core to counteract the field produced by DC current. This magnetic field is generated by an additional winding: the compensation winding. The required DC current is determined by sensors at the active part and controlled by a control unit. The magnetic field generated by the DC current on the grid side and that generated in the compensation winding cancel each other out in the core. This results in an AC field that equals the one in the transformer core during normal operation. The DC effects on transformer noise level can be nearly completely eliminated with DC compensation activated. The same is also applicable for no-load losses. Thus, noise and no-load losses decrease to almost original levels without DC present. Therefore, active DC compensation is the solution of choice for continued low-loss and low-noise transformer operation when DC is already in the grid.

External solutions to cope with DC would be:

- Low Noise Transformer without DCC – more sensitive to DC effect
- Installation of external noise protection walls – highly expensive/not always possible
- Implementation of DC blockers – ineffective for DC asymmetric loading and depending on neutral accessibility, not effective on Autotransformer – within Siemens portfolio for retrofitting

DC-ready configuration

In order to prepare for the future with changing grid topology and increasing renewable generation, power transformers should be ready for DC in the grid. Siemens transformers can be designed “DC ready.” The active parts of these transformers are already equipped with all required components for DC compensation, like compensation winding, internal measurement sensors, and connections. The control unit is not yet included for DC-ready transformers and can easily be retrofitted later, based on the actual amount of DC in the grid.