Design and study of a novel series active filter for the 10MW-level high power and high stability DC power supply

1. SAPF for 10MW-level high power and high stability DC power supply

The obstacle to improve current ripple is the uselessness of the suppression of low-frequency (50-150Hz) voltage ripple by the LC passive filter. To improve this parameter, the common method used is to add a Series Active Power Filter (SAPF) device at the output end, which includes two ways: transformer coupled current injection and transistor linear adjustment.

2. Operating Principle of the novel SAPF

1. The novel SAPF is designed as a voltage source that directly tracks the negative value of the output voltage ripple of the main power supply \( -U_{source} \times \).
2. If its response speed is fast enough, it can be regarded as an ideal voltage source. Then it can be directly connected in series with the main power supply without changing its control strategy.
3. Working sequence of main power supply and SAPF:
   1. The SAPF is started first to control the rise of magnet current by controlling the rise rate of \( U_{dc,ref} \).
   2. It can effectively solve the problem of uneven output waveform in the initial stage of current climbing.

4. Control policy of the novel SAPF

- Fast current inner loop is used to realize automatic current equalization between sub-modules.
- The recommended response speed of the current loop is 10 times that of the voltage loop.

5. Extraction of the output voltage ripple of the main power supply

- The extraction ratio of the AC component on \( U_{c} \) is:
  \( K_{e} = K_{c} / K_{i} \)
- The extraction of the DC component on \( U_{c} \) is:
  \( K_{D} = K_{D} / R_{ins} \)
  insulation resistance of \( C_{i} \)

6. Experimental verification

- Experimental results:
  1. The ripple components in \( U_{c} \) are mainly 250Hz and 300Hz.
  2. Peak-to-peak value of \( U_{c} \) is about 0.2V.
  3. \( U_{c} \) is basically coincident with \( U_{m} \), and there is no phase lag.
  4. \( U_{m} \) and \( U_{c} \) basically coincide, and there is no phase lag.
  5. Peak-to-peak value of \( U_{c} \) after novel SAPF filtering is about 50mV.

- Related experimental parameters:
  1. Main power supply is a 50V/50A SCR rectifier bridge.
  2. The dummy load is 5mH/0.70hms copper coil.
  3. The small prototype uses two groups of sub-modules in parallel. Each submodule outputs 10V/50A.
  4. The response speed of the current inner loop is designed as 20kHz, and the voltage outer loop is designed as 20kHz.
  5. H bridge adopts silicon carbide MOSFET, and the working frequency is 100kHz.
  6. According to the above calculation formula, the output capacitance \( C_{j} \) is set to 1.6mF. Accordingly, the output capacitance of each submodule is set to 0.8mF.