Claims

1. A method of controlling a Solid State Transformer (SST) comprising:

dividing a dual active bridge (DAB) power reference by a Low Voltage (LV) side Direct Current (DC) link voltage to obtain a total DAB reference current ;

dividing the total DAB current reference by *N* number of DAB modules to obtain a reference current for each DAB module;

in response to SST being in a normal power regulation, determining a deviation of a capacitor voltage at the HV side of each of a *k* DAB modules with reference from an average voltage from the HV DC bus;

determining a current adjustment signal for each of the *k* DAB modules based on the total DAB reference current and a corresponding deviation of the capacitor voltage of each of the *k* DAB modules;

adding the current adjustment signal together with the reference current for each DAB module to obtain a total current reference for each of the *k* DAB modules; and

subtracting a sum of the total current reference of each of the *k* DAB modules from the total DAB reference current to determine a total current reference of an N^{th} DAB module, wherein $k = 1,..., N - 1$.

2. The method of controlling the SST according to claim 1 wherein the step of determining the current adjustment signal for each of the *k* DAB modules based on the total DAB reference current and the corresponding deviation of the capacitor voltage of each of the *k* DAB modules comprises:

multiplying the deviation of the capacitor voltage at the HV side of each of the *k* DAB module, a load dependent voltage balancing proportional compensation gain, and a magnitude of the reference current for each of the *k* DAB modules, the voltage balancing proportional compensation gain can be positive values which can be obtained from a look-up table.

3. The method of controlling the SST according to claim 2 wherein the current adjustment signal is saturated before adding together with the reference current for each DAB module to obtain the total current reference for each of the *k* DAB modules.

4. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being positive, increasing the magnitude of the reference current for a DAB module with higher deviation of the capacitor voltage.

5. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being negative, reducing the magnitude of the reference current for a DAB module with higher deviation of the capacitor voltage.

6. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being positive, reducing the magnitude of the reference current for a DAB module with lower deviation of the capacitor voltage.

7. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being negative, increasing the magnitude of the reference current for a DAB module with lower deviation of the capacitor voltage.

8. The method of controlling the SST according to claim 1 further comprising:

in response to SST being in a normal power regulation, applying the reference current of each DAB module as the total current reference for each DAB module.

9. The method of controlling the SST according to claim 8 further comprising:

in response to SST being in the normal power regulation, enforcing minimum HV side reactive power.

10. The method of controlling the SST according to claim 1 further comprising:

linearizing a current and voltage in each DAB module.

11. The method of controlling the SST according to claim 10 wherein the step of linearizing the current and voltage in each DAB module comprises:

applying a non-linear compensation function between a proportional-integral (PI) controller and a DAB plant, the non-linear compensation function being

$$\frac{\beta}{x} = \frac{1}{V_{DC_{HV}} * \cos(\frac{\alpha_{1_1}+\alpha_{1_2}}{4}) * \cos(\frac{\alpha_2}{2})}$$

where $V_{DC_{HV}}$ refers to capacitor voltage at the HV side of each DAB module, $\alpha_{1_1}, \alpha_{1_2}, \alpha_2$ are phase shift angles from the DAB plant, β refers to the input of the DAB plant and x refers to the output of the PI.

12. The method of controlling the SST according to claim 11 wherein the step of linearizing the current and voltage in each DAB module further comprises:

passing a low voltage output current through a low pass filter and using the filtered output current as a feedback signal;

obtaining a difference between an input current and the feedback signal and passing a signal representing the difference through a proportional-integral (PI) controller and the non-linear compensation function; and

performing linearization of a voltage by using a square of a low voltage output voltage as a feedback signal to the reference voltage.

CLAIMS:

1. A method of controlling a Solid State Transformer (SST), the method comprising:

dividing a dual active bridge (DAB) power reference by a Low Voltage (LV) side Direct Current (DC) link voltage to obtain a total DAB reference current;

dividing the total DAB reference current by N number of DAB modules to obtain a reference current for each DAB module;

in response to the SST being in a normal power regulation, determining a deviation of a capacitor voltage at the HV side of each of a k DAB modules with reference from an average voltage from the HV DC bus;

determining a current adjustment signal for each of the k DAB modules based on the total DAB reference current and a corresponding deviation of the capacitor voltage of each of the k DAB modules;

adding the current adjustment signal together with the reference current for each DAB module to obtain a total current reference for each of the k DAB modules; and

subtracting a sum of the total current reference of each of the k DAB modules from the total DAB reference current to determine a total current reference of an N^{th} DAB module, wherein $k=1, \ldots, N-1$.

2. The method of controlling the SST according to claim 1 wherein the step of determining the current adjustment signal for each of the k DAB modules based on the total DAB reference current and the corresponding deviation of the capacitor voltage of each of the k DAB modules comprises:

multiplying the deviation of the capacitor voltage at the HV side of each of the k DAB modules, a load dependent voltage balancing proportional compensation gain, and a magnitude of the reference current for each of the k DAB modules.

3. The method of controlling the SST according to claim 2 wherein the current adjustment signal is saturated before adding together with the reference current for each DAB module to obtain the total current reference for each of the k DAB modules.

4. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being positive, increasing the magnitude of the reference current for a DAB module with higher deviation of the capacitor voltage.

5. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being negative, reducing the magnitude of the reference current for a DAB module with higher deviation of the capacitor voltage.

6. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being positive, reducing the magnitude of the reference current for a DAB module with lower deviation of the capacitor voltage.

7. The method of controlling the SST according to claim 2 further comprising:

in response to the total current reference of the N^{th} DAB module being negative, increasing the magnitude of the reference current for a DAB module with lower deviation of the capacitor voltage.

8. The method of controlling the SST according to claim 1 further comprising:

in response to the SST being in a normal power regulation, applying the reference current of each DAB module as the total current reference for each DAB module.

9. The method of controlling the SST according to claim 8 further comprising:

in response to the SST being in the normal power regulation, enforcing minimum HV side reactive power.

10. The method of controlling the SST according to claim 1 further comprising:

linearizing a current and a voltage in each DAB module.

11. The method of controlling the SST according to claim 10 wherein the step of linearizing the current and the voltage in each DAB module comprises:

applying a non-linear compensation function between a proportional-integral (PI) controller and a DAB plant, the non-linear compensation function being

$$\frac{\beta}{\chi} = \frac{1}{V_{DC_{HV}} * \cos\left(\frac{\alpha_{1_1} + \alpha_{1_2}}{4}\right) * \cos\left(\frac{\alpha_2}{2}\right)}$$

where $V_{DC_{HV}}$ refers to capacitor voltage at the HV side of each DAB module, α_{1_1}, α_{1_2}, α_2 are phase shift angles from the DAB plant, β refers to the input of the DAB plant and χ refers to the output of the PI.

12. The method of controlling the SST according to claim 11 wherein the step of linearizing the current and the voltage in each DAB module further comprises:

passing a low voltage output current through a low pass filter and using the filtered output current as a feedback signal;

obtaining a difference between an input current and the feedback signal and passing a signal representing the difference through a proportional-integral (PI) controller and the non-linear compensation function; and

performing linearization of a voltage by using a square of a low voltage output voltage as a feedback signal to the reference voltage.

13. The method of controlling the SST according to claim 2 wherein the voltage balancing proportional compensation gain is a positive value and/or obtained from a look-up table.