Transfer between 66 kV and 22 kV ac input power lines with external thyristor bypass switches in the ITER TF converter

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1. Introduction

The ITER Toroidal Field Converter will be a 12-pulse, 2-quadrant converter rated for 68 kA current, 900 V no-load voltage. The converter is designed as a single unit with two thyristor 6-pulse bridges connected in parallel via DC reactors. The bridges are supplied by a rectifier transformer with two secondary windings shifted by 30 °.

When the TF system has been charged and the current has reached the requested constant value, the primary winding of the rectifier transformer is switched from the 66 kV ac to the 22 kV ac to reduce reactive power. Also, when it is needed to discharge the coils in about half an hour, the ac supply have to change from 22 kV to 66 kV for fast current discharge[1]. While switching the ac supply from 66 kV to 22 kV or vice versa, the use of internal or external bypass switch(es) are necessary.

In this paper, the procedure of the transfer operations between 22 kV and 66 kV ac power lines with external thyristor bypass switches are studied and analyzed by using computer program PSIM.

2. Procedure of Transfer Operations

The brief procedure of transfer operations between 22 kV and 66 kV ac power lines with external thyristor bypass switches is shown in Figure 1.

For transfer from 66 kV to 22 kV;

1. Gates of thyristor bridges blocked and bypass switches are fired so the coil current bypassed through the bypass switches.
2. Then 66 kV ac circuit breaker is opened and 22 kV circuit breaker is closed.
3. After ac power lines are changed, gates of thyristor bridges are fired again and the thyristor bridges come back to the normal operation mode with external thyristor bypass switches turned-off.

For transfer from 22 kV to 66 kV, the procedure is similar to that of the previous procedure, that is;

1. Gate blocked.
2. Bypass switches are turned- on.
3. 22 kV circuit breaker is opened and 66 kV circuit breaker closed.
4. Gates of thyristor bridges are fired again and the bypass switches are turned-off.
5. The α may jumped up to inversion angle for fast current discharge of the TF coils.

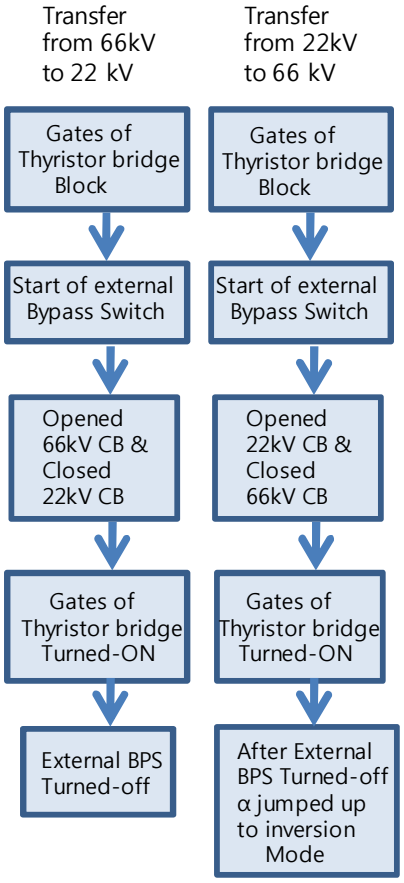

Figure 1. Procedure of transfer operations between 22 kV and 66 kV ac power lines.

3. Simulation and Results

According to the transfer procedure, simulations are performed with a computer program PSIM. Figure 2, Figure 3 are the main simulation circuit and simplified one, respectively. In Figure 3, the two external thyristor bypass switches, BPS-1 and BPS-2

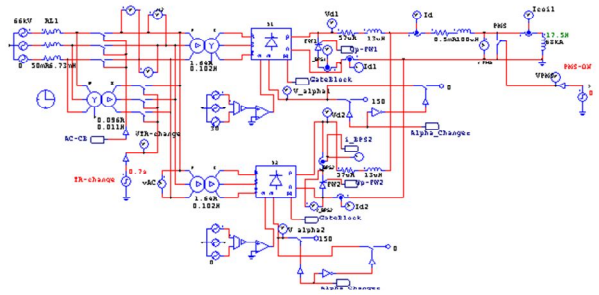

Figure 2. Main simulation circuit

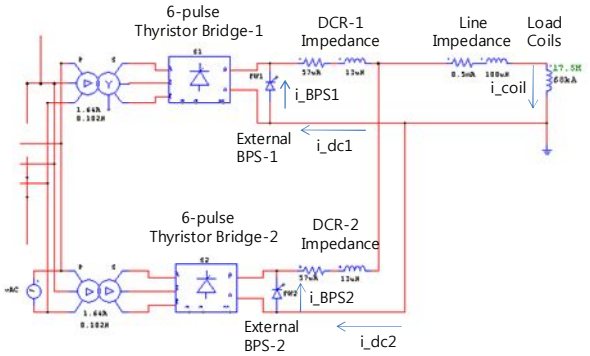

Figure 3. Simplified main circuit.

are connected across the output terminals of the thyristor bridges. The resistances and inductances of the DC reactors DCR-1, DCR-2 are 57μΩ, 13 μH, respectively and the resistance and inductance of the busbar between the converter and TF coils are 0.5 mΩ, 100 μH.

Figure 4 is current waveforms resulted from a simulation during transferring input voltages from 66 kV to 22 kV. In figure 4, the upper waveform is a current of the coil, the middle one is the current of the busbars between TF coil and two 6-bridges, and the lower one is the current of the two external bypass switches.

At time t=0.5s, gates of bridge thyristor are blocked and bypass switches are fired to turned-on. At t=0.7s, input voltage transferred from 66 kV to 22 kV and at t=0.8s, gates of bridge thyristors are fired again and bypass switches blocked by output voltages of the converters.

Before gates blocked, the converter is in rectifier mode and the coil current increase with the rate about 40A/s. During gate blocking period, the current decreases and when gates fired again, the current increases again but the increasing rate is decreased because of decreased input voltage.

When gates blocked and bypass switches turned-on, the 68 kA coil current bypassed through two bypass switches. At that bypass period, one of bypass current $i\_BPS1 = i\_dc1$, and the other current $i\_BPS2 = i\_dc2$. The initial currents through the BPS1 and BPS2 are 60 kA, 8 kA, respectively.

Figure 5 is current waveforms resulted from a simulation during transferring input voltages from 22 kV to 66 kV. In figure 5, the timing sequences and the upper, middle, and lower waveforms are the same arrangements with figure 4.

Before gates blocked, the increasing rate of the coil is slower than the rate in figure 4 and when the transfer actions have finished, the increasing rate increased. At bypass period, one of bypass current $i\_BPS1 = i\_dc1$, and the other current $i\_BPS2 = i\_dc2$ and the initial currents through the BPS1 and BPS2 are 40 kA, 28 kA, respectively.

It is guessed that the initial unbalanced currents between BPS1 and BPS2 come from 30° phase differences of the bridges. The unbalanced factor(i_BPS1/i_BPS2) and unbalanced period($t = L/R$) are depend on the impedance parameters of the DC Reactors(DCR-1, DCR-2).

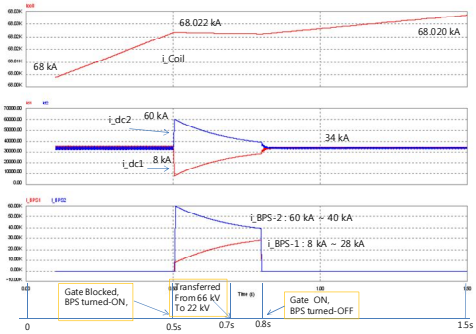

Figure 4. Results of simulation during transferring input voltage from 66 kV to 22 kV.

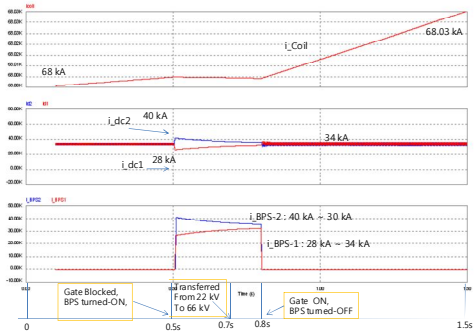

Figure 5. Results of simulation during transferring input voltage from 22 kV to 66 kV.

4. Conclusions

From the simulation, it is shown that the transfer operations between 22 kV and 66 kV ac power lines are successfully performed with bypassing the coil current to the external thyristor bypass switches.

Also, it is shown that without any other actions, just blocking of the gates of the thyristor bridges and firing the gates of the external bypass switches are enough for bypassing the coil current to the bypass switches.

5. References

[1] Design Description Document (DDD 4.1) for the ITER Pulsed Power Supplies, 2001.