Reactive power compensation in ITER power supply system

Churl-Kew Hwang[a*], Byung-Hoon Oh[a], Kwang-Won Lee[a], Jeong-Tae Jin[a], Dae-Sik Chang[a], Jong-Seok Oh[b], Jungwan Choi[b], Jae Hak Suh[c]
[a]*Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea*
[b] *National Fusion Research Institute, Gwahangno 113, Yuseong-gu, Daejeon, 305-806, Korea*
[c]*Pohang Accelerator Laboratory, San-31 Hyoja-dong, Pohang, Kyungbuk, 790-784, Korea*
[*]*Corresponding author: kew@kaeri.re.kr*

1. Introduction

ITER power supply system supplies the heating and current driving facilities and the magnetic coils which will typically produce the reactive power up to 930Mvar in full load operation of 500MW active power. The high voltage grid allows about 200Mvar and the reactive power compensator (RPC) of 795Mvar is planned.

The control strategy of RPC is important because of the over voltages from abrupt changes of the load. Some or whole units of the load could be cut off in normal operations as well as in accidents.

ITER RPC consists of TCR (thyristor controlled reactor) and capacitors with fixed values. The control, in strategy, calculates the susceptance of the load from the load current and drives TCR to keep the total susceptance at the given level.

The control circuit is simulated using a commercial software, PSIM, and the over voltages are tested for typical cases of load loses. In order to respond as fast as possible and thereby reduce the peak values of transient over voltages, a scheme is suggested in which the signals of the susceptance change and the timing are provided by the load controllers. The improvements are also simulated by PSIM.

2. Control of RPC

The basic operation of RPC is to control TCR to compensate or to cancel the susceptance in the load. Thereby, the ac voltage drop could be reduced as well as reduction of the reactive power absorbed by the grid.

The susceptance of the load can be calculated by monitoring the load current. In the simulation, the current of the load and RPC *Itot* and the current of RPC *Irpc* are measured separately. Also, the common voltage *V* of the load and RPC is monitored and used to calculate the susceptance. The total susceptance *Btot*, for example, is calculated as

$$Btot = \mathrm{im}(V^{*}Itot)/|V|^2 = (Vr\ Itoti - Vi\ Itotr)/|V|^2 \qquad (1)$$

Here, "im" means "the imaginary part of ". *Vr* and *Vi* are real and imaginary components of *V*, respectively. Similarly, *Itot* = *Itotr* + j *Itoti*.

The output of the control circuit is the delay angle α to TCR. α is a function of the ratio *BrpcIn*/*BrpcN*, where *BrpcIn* is the susceptance to be produced by TCR and *BrpcN* is the rated or the maximum susceptance of TCR. The time response of RPC to *BrpcIn* is designated as *Brpc*. *BrpcN* from three units of RPC with the unit capacity 265MVar/66kV is *BrpcN* = 795MVar/(66kV)^2 = 0.1825 mho. In the control, *BtotRef* is used as the reference to the total susceptance. Thus, the control equation producing *BrpcIn* can be written as

$$BrpcIn = (BtotRef - Btot) + Brpc. \qquad (2)$$

By setting *BtotRef* = 0, a complete cancel of the load susceptance is accomplished unless the value is greater than the limit of RPC, *BrpcN*. Fig. 1 shows the circuit calculating the ratio *bRPC* = *BrpcIn*/*BrpcN*, the total power *Ptot*, and the total reactive power *Qtot*.

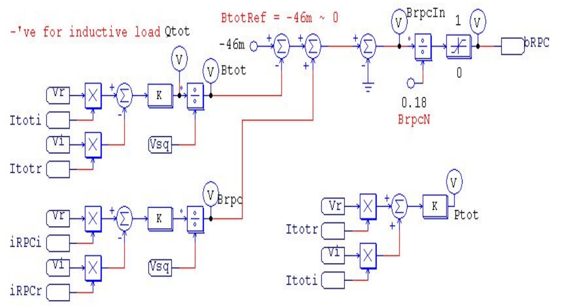

Figure 1. The circuit for *Ptot*, *Qtot*, and *BrpcIn*/*BrpcN*.

Fig. 2 shows the main circuit of simulation. It consists of the power source of 66kV, TCR, the harmonic filter, HC, and one 12-pulse converter. The 66kV source represents the equivalent source seen at the secondary side of the step down transformer 400kV/66kV. *bRPC* in Fig. 1 drives TCR through the susceptance-to-alpha converter as shown in Fig. 2.

3. The results of simulation

3.1 Scenario 1 (Partial cut of load)

After the full load with RPC control goes into the steady state, HC is cut off abruptly by the ac switch at 0.5sec. Fig. 3 shows the results of simulation with the

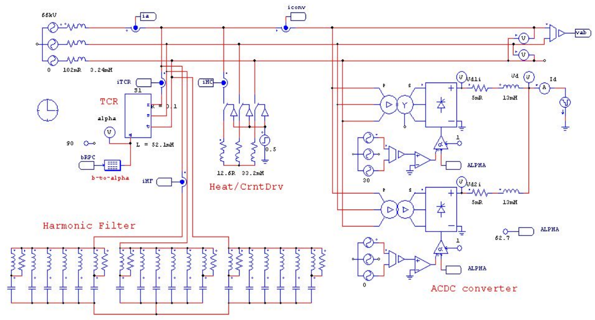

Figure 2. The main circuit for RPC and the loads.

grid capacity Sg =10GVA.

In full load state, *Ptot* becomes greater than the nominal 500MW even with *U* less than 66kV. RPC has resistive components and absorbs some real power. In this case of simulation, the control parameter *BtotRef* is set such that, in terms of reactive power, *QtotRef* = 0.

In the full load state, RPC cannot completely cancel the reactive power produced by the load. Thus, -118Mvar remains. The negative sign means that the reactive power is "inductive."

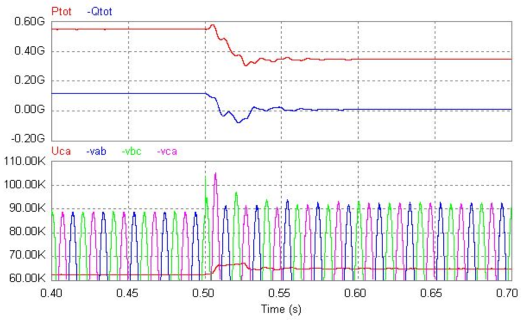

Figure 3. The powers *Ptot*, *Qtot* (top plot), the rms voltage *U*, and the voltage waveforms (bottom plot) when HC is cut off: *Sg* = 10GVA, *QtotRef* = 0.

3.2 Scenario 2 (The whole load cut off)

After the full load with RPC control goes into the steady state, the whole load is cut off. HC is cut off abruptly. And at the same time, the converter is cut off by making *Id* = 0 in 7.5msec. This is the worst case and gives the maximum over voltage in the transient response.

In Table I, the transitions are summarized. The peak values represent the highest peak in the response to the loss of the load. The percentage is referred to the nominal voltages 66kVrms and $\sqrt{2}$ 66 = 93.3kV amplitude. The simulation result for the grid capacity 6GVA is also shown in the table.

3.3 Fast control

For the scenario 2, the worst case, an open-loop control is simulated. In this control, the timing at which the load is cut off is assumed to be controllable and could be sent to RPC together with the information about the load current to be cut off.

Table I: Changes in *Ptot*, *Qtot*, voltages when the whole load is cut off

10GVA 0MVar	from	to	
		Peak value	Steady value
|*Vab*| rms kV	62.6 (-5.2%)	79.4 (20%)	66.0 (0.0%)
Vab amplitude kV	88.7 (-5.0%)	129 (38%)	93.7 (0.3%)
Ptot MW	547		6.24
Qtot MVar	118		0.879
6GVA 0MVar	from	to	
		Peak value	Steady value
|*Vab*| rms kV	61.4 (-7.0%)	87.0 (32%)	66.0 (0.0%)
Vab amplitude kV	86.9 (-6.9%)	145. (55%)	93.6 (0.3%)
Ptot MW	558		6.25
Qtot MVar	112		0.451

In the circuit of Fig.1, there is an unused summation component with one port grounded. The open-loop part is connected to this port. The simulation results shows that the transient over voltages are reduced significantly. The reductions are summarized in Table II. *QtotRef* was set to zero for both 10GVA and 6GVA. The change of *QtotRef* with the open-loop component has negligible effect on the reduction of the over voltages.

Table II. The transient voltages when the whole load is cut off in the fast control mode.

10GVA 0MVar	Open-loop	
	off	on
|*Vab*| rms kV	79.4 (20%)	69.6 (5.5%)
Vab amplitude kV	129 (38%)	109 (17%)
6GVA 0MVar	Open-loop	
	off	on
|*Vab*| rms kV	87.0 (32%)	70.4 (6.7%)
Vab amplitude kV	145. (55%)	112 (20%)

4. Conclusions

The simulations show that the worst case, Scenario 2 with 6GV, gives the transient over voltages in rms value 32% of the nominal voltage. In that case, the instantaneous voltage peak rises to 55%.

To reduce the transient over voltages, a fast control using a link between RPC and the load control system is tried to make an open-loop component. The simulation with the link gives, in the worst case, the rms value 6.7% and the instantaneous voltage peak 20% as shown in Table II.

5. Acknowledgements

The authors wish to thank Dr. Ivone Benfatto, Dr. Jun Tao, and Dr. Inho song for the helpful discussions during the review of the work reported in this paper.