INTRODUCTION

The Toroidal Field system of the JT-60SA tokamak is composed of 18 NbTi superconducting coils. Each TF coil is composed of 6 cable-in-conduit conductor lengths, wound in double-pancakes, carrying a nominal current of 25.7 kA. These coils are being tested in the single coil configuration at the so-called Cold Test Facility (CEA/IRFM Saclay, France). The test program includes for all coils a DC operation for one hour at nominal temperature (4.7 K) and nominal current followed by a progressive operating temperature increase up to quench (around 7.5 K inlet temperature). Thanks to the accuracy of the fast Data Acquisition System at 10 kHz sampling rate which is triggered by the quench, but which allows the measurement of the six double-pancake voltage drops up to 10 s before the magnet fast discharge, it has been possible to follow the very early development of the quench at the scale of a few millimeters normal (i.e. non-superconducting) in length. In addition, this early quench development over one conductor length was also simulated using the THEA code with relevant boundary conditions. Two different quenches which occurred on two different coils are analyzed: one starting on a central pancake winding which corresponds to the peak magnetic field, the other starting on a side pancake corresponding to a more heated conductor due to heat transfer from the casing.

Current sharing and Quench tests vs. THEA Simulation: Side DPs (SDPs)

- Very close signals for all coils resistive voltage drops up to 12 mV
- Significant scattering above (up to 0.43 s in time to reach 100 mV = OD threshold)
- Good agreement between THEA simulation (inner turn of C11 P12) and experiment

Three phases identified in early quench development after a slow stable voltage increase

1. Fast voltage growth due to combination of both transition zone extension and temperature increase (from TCold to TC)
2. Slower voltage growth (after a knee) due to only normal zone extension (with TC < Tc(peak) < 21 K)
3. Quench acceleration due to helium expulsion, particularly toward helium inlet (reverse flow)

Current sharing and Quench tests vs. THEA Simulation: Central DPs (CDPs)

Again, good agreement between THEA simulation (inner turn of C13 P8) and experiment

Very similar behaviour to SDPs with the same 3 phases due to very similar magnetic field profiles along the inner turns

CONCLUSION

Twelve TF coils among twenty (18 + 2 spare coils) of the JT-60SA tokamak have been tested by a transient increase of helium inlet temperature up to quench at nominal current. All coils show quite similar results in terms of quench temperature but with quench locations varying from coil to coil. Thanks to an accurate fast DAS it has been possible to measure each double-pancake resistive voltage before the fast safety discharge is triggered. The analysis of these signals has been complemented by a simple one-turn numerical modeling using the THEA code. Results of simulations are in good agreement with experiment, which allows better understanding the early quench development, particularly 3 phases have been identified corresponding to 3 parts of the voltage drop evolution associated with 3 physical phenomena. Little differences have been observed between central and side pancakes’ quenches which is not surprising taking into account the low normal zone extension (about 2.8 m) before the coil is discharged, which also explains why our 1-D single conductor model has turned out to be so effective in modeling the early quench development.