JT-60SA Newsletter
No.43, 31 July 2013

Headline

Successful cooling and electrical current tests for CS model coil

Figure 1: CS model coil before installation

Figure 2: Cryostat for testing the CS model coil at NIFS

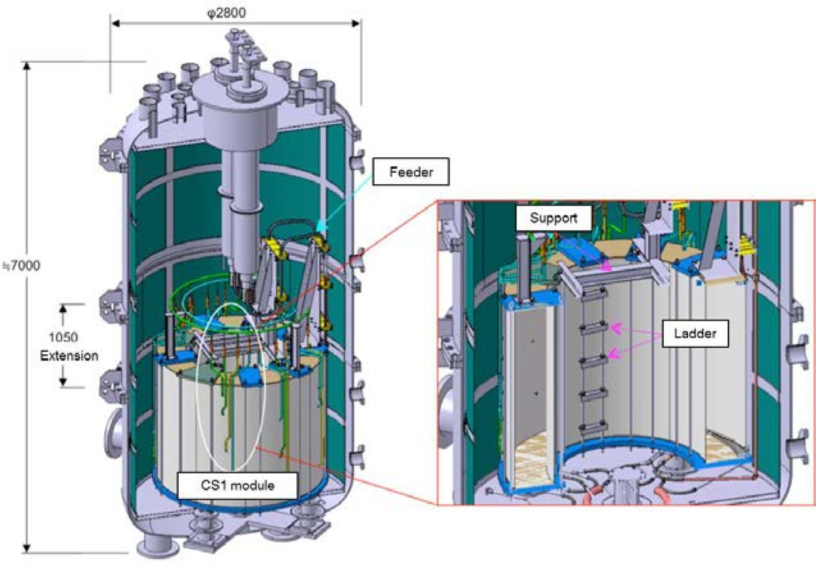


Figure 3: Modification of forced-cooled conductor test rig for the CS1 module

The central solenoid (CS) of JT-60SA is composed of four identical modules to satisfy the plasma shaping requirements and minimize the number of current leads. The modules can be energized independently. The module is a solenoid of mean radius 0.822 m, 0.34 m wide and 1.6 m high. Each winding pack consists of six 8-layer-pancakes and one 4-layer-pancake.

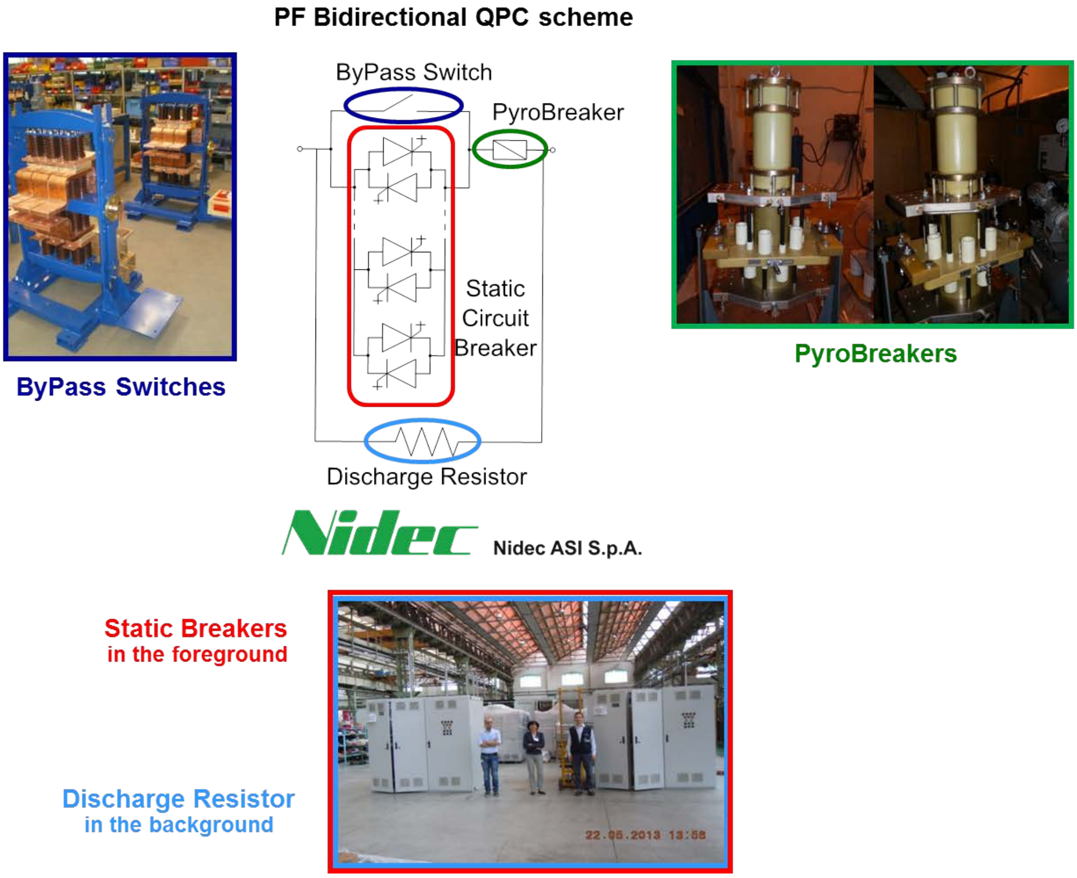
A 4-layer-pancake CS model coil was manufactured to qualify tools and conditions in all manufacturing processes (Figure 1). This model is practically identical to the 4-layer pancake of the CS module. The cold test of the CS model coil, installed in the test cryostat at the National Institute for Fusion Science (NIFS) (Figure 2), was performed after installation of the force-cooled conductor test rig.

As a result, it was successfully verified that the specified resistance value of 2.5 nΩ and flowing current of 30 kA are satisfied, and there was no technical problem with the manufacturing method. Consequently, the green light to go ahead with manufacturing the real CS modules has been given.

In addition, a modification of the force-cooled conductor test rig used for this test of the CS model coil (to extend its height by 1,050 m) was planned, so as to be able to perform a cold test of the CS 1 module (Figure 3) in NIFS next year.

News

Manufacture and test of the two QPC pre-series units



After the successful type tests on the toroidal field (TF) and poloidal field (PF) quench protection circuit (QPC) prototypes, which achieved the second milestone of the QPC procurement in January 2013, the manufacture and testing of the two QPC pre-series production - one for the TF and one for the PF coil circuit - has been completed in June 2013, on schedule.

The JT-60SA QPC system, procured by the Italian National Research Council acting through Consorzio RFX via a contract awarded to the company Nidec ASI in December 2010, consists of thirteen units: three for the TF coils and ten for the PF coils.

Each QPC is basically a circuit breaker designed to sustain the superconducting coil current in normal operation and rapidly transfer it into a discharge resistor capable to dissipate the magnet energy in case of coil quench or other faults requiring a fast coil de-energisation. The high reliability required for the system is improved by an explosively actuated circuit breaker (named pyrobreaker) acting as a backup protection in case of failure of the main circuit breaker.

The main circuit breaker (CB) is an innovative hybrid design composed of a mechanical bypass switch (BPS) paralleled to a static circuit breaker (SCB), assuring low operational losses and arc-less current commutation from the SCB to the discharge resistor, thus implying low maintenance requirements.

This is the first DC circuit breaker to use the hybrid mechanical-static scheme at the level of power required by JT-60SA (25.7 kA – 1.93 kV, ±20 kA – ±3.8 kV). Moreover, the JT-60SA QPC is the first application of protection for superconducting magnets based on this hybrid technology.

The QPC components have been manufactured at the main supplier and sub-supplier premises: SCB at Nidec ASI in Milan (Italy), BPS at Siemens/Ritter in Wilnsdorf (Germany), discharge resistor at Telema in Milan (Italy), pyrobreaker at Efremov Scientific Research Institute in St. Petersburg (Russian Federation), and sent to Nidec ASI in Milan for the final assembly of the QPC units.

All components have been subjected to a complete set of routine tests to verify the quality of the manufacturing processes. At the end of June 2013, the successful result of all the tests carried out allowed Consorzio RFX to give the go-ahead for the manufacturing of the remaining QPC units.

News

Successful first tests on central solenoid breakdown resistors

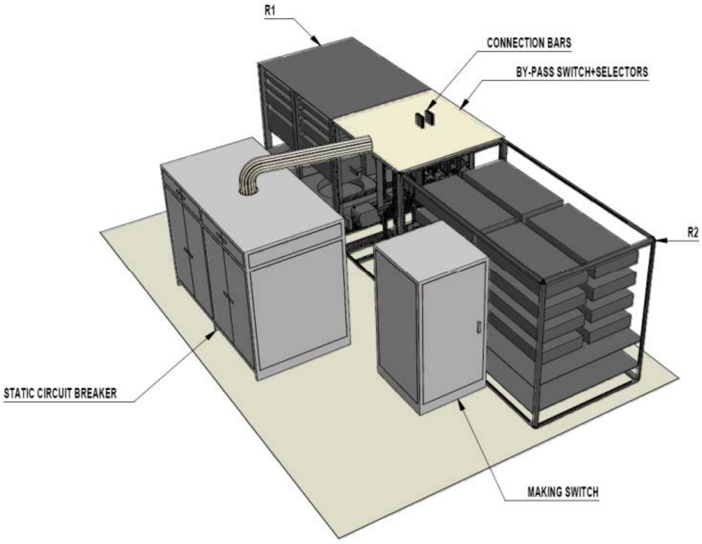


Figure 1: Layout of a JT-60SA central solenoid SNU

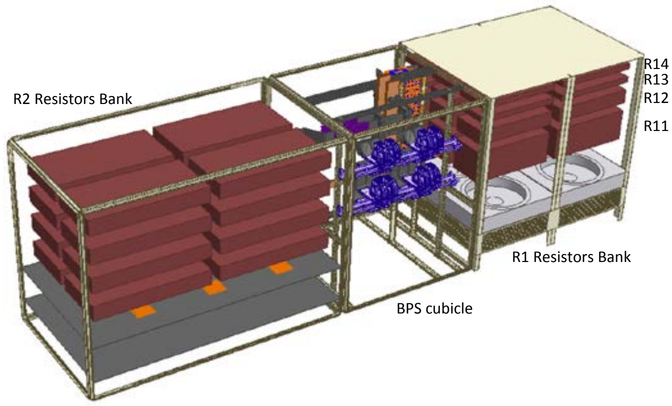


Figure 2: The R1 and R2 assemblies in the final SNU layout beside the electromechanical by-pass switch (BPS) cubicle

Figure 3: The two tested resistors banks with the ENEA, F4E, OCEM ET and Microlettrica Scientifica representatives

The four switching network units (SNUs) for the JT-60SA central solenoid (Figure 1) are being procured by ENEA through a contract signed in October 2012 with the industrial supplier OCEM Energy Technology.

OCEM ET presented its technical proposals for the first design report throughout spring 2013 and they are being reviewed by all the involved partners. The design choices are under validation by preliminary tests on prototypes of the most critical parts of the SNU, such as the electronic static circuit breaker (SCB) and the breakdown resistors. The first type tests on the breakdown resistors denoted as R1 (Figure 2) were performed on 10-11 June 2013 in the premises of the manufacturer Microelettrica Scientifica, located in Milan, Italy. Besides the OCEM ET representatives, the activities were attended by A. Lampasi on behalf of ENEA and L. Novello on behalf of F4E.

The SNU technical specifications prescribe to perform the type tests on the minimum quantity of resistor modules based on the same design. Since, according to the final design, two different basic modules are foreseen in the R1 bank (one to form the resistances R11, R12, and R13, another only as R14), two resistor units (R13=1.875 Ω, R14=3.75 Ω) were tested.
The resistance value of each resistor was measured at 20 °C by a Kelvin Bridge and was well within the prescribed 2 % of the nominal value. Moreover, it was agreed to repeat these measurements on all the resistors (routine test) after assembling them in the cubicles, allowing a check of the connections and any other undesired contributions.

The inductance, measured at 1 kHz by an LCR instrument, was below 10 µH. According to the OCEM ET design, this will allow to obtain an SNU opening time shorter than 1 ms and a transient voltage lower than 6 kV.

The most critical test was the "temperature rise test", consisting of dissipating adiabatically the resistor nominal energy and verifying that the resistance variation is less than 10 %. Due to the available sources, the current pulse duration will be longer than the minimum SNU operating time, but much shorter than the thermal time constant of the resistors. Moreover, the energies injected during the tests were always higher than the nominal ones. In these situations, the measured resistance variations were in the range of 7-8 %.

Such a test was repeated at least 10 times for each module with repetition times shorter than the JT-60SA operation time (1,800 s dwell), without observing mechanical deformations. As the resistor cubicles will be equipped with fans to force the cooling air, some tests will be repeated in the definitive assembly with the actual fans, achieving thermal time constants under 100 s.

The type tests and the discussions with the manufacturers allowed an appreciation of other interesting features of the SNU design. For example, the breakdown resistors can dissipate much more energy (and maintain lower temperature) than requested by the technical specifications (even 3-4 times the nominal ones, in the manufacturer estimations), ensuring an adequate safety margin even in the case of a system fault. In fact, during the tests the resistor R13, rated 4 MJ in the JT-60SA design, was overloaded with over 8 MJ without problems. Moreover, the temperature of the selected material is expected to increase less than 80 °C during the most severe operations, guaranteeing that the exhaust air temperature from the resistor cubicle to the JT-60SA rectifier room will be lower than 20 °C.

All the described tests will be repeated on the breakdown resistors of the bank R2, as they are based on a different design.

News

Inboard and outboard segments for seventh 40° VV sector delivered

Figure 1: Outboard segment being unloaded at Naka

Figure 2: Inboard segment stored in the VV assembly building

The inboard and outboard segments for the seventh 40° sector of the vacuum vessel (VV) were delivered to the Naka site in July after fabrication and surface treatment at the factory with a glass bead blaster for the inner surface and a buffing method for the outer surface.

The VV consists of ten sectors: seven 40° sectors, two 30° sectors and one 20° sector. Therefore, this was the very last 40° sector to be delivered to the Naka site. The manufacture of the eighth and ninth sectors (30°) is progressing well and the inboard and outboard segments for the eighth sector will be delivered this September. According to this schedule, the inboard and outboard segment welding for the seventh 40° sector will be started in the same month.

News

Modification work of N-NBI started

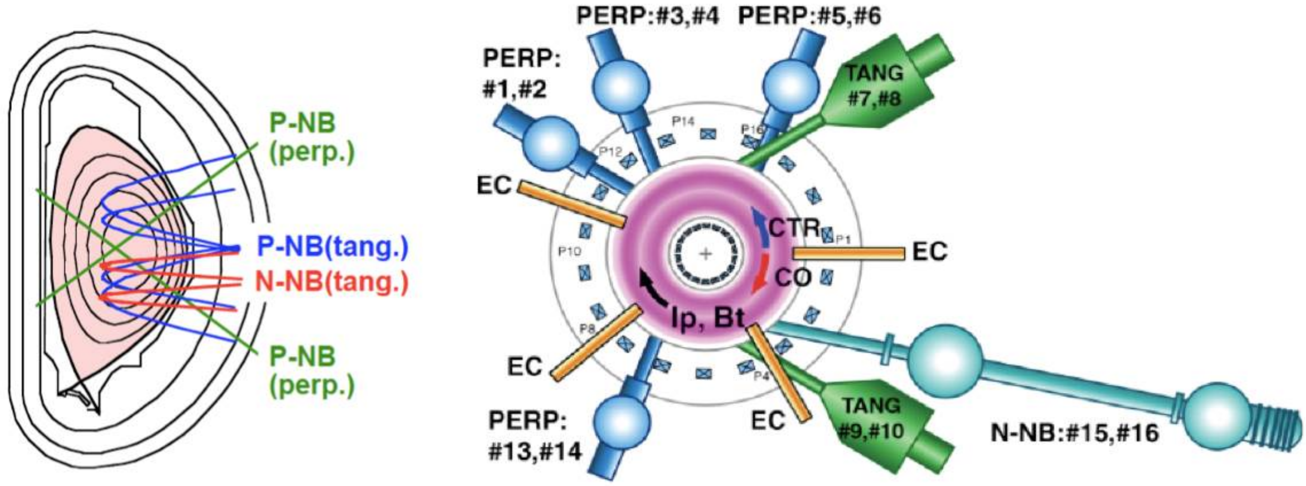


Figure 1: Heating systems for JT-60SA and NB injection trajectories

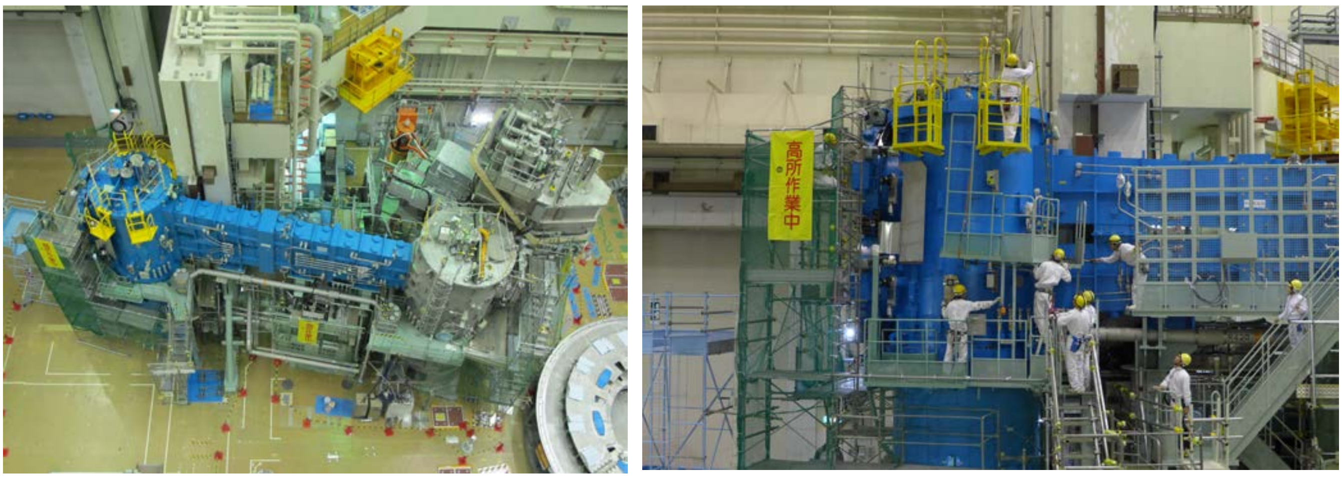


Figure 2: N-NBI system and modification work for lowering the beamline injection position

The JT-60SA neutral beam injectors (Figure 1), with a full injection power of 34 MW x 100 s, allow a variety of heating/ current-drive/momentum-input combinations. In particular, the negative ion based natural beam injection (N-NBI) system (green in the figure) is one of the most advanced systems in JT-60SA. It provides 10 MW/500 keV co-tangential injection and consists of two beams (5MW each) with different injection trajectory. One is relatively on-axis and the other is slightly off-axis compared to the magnetic axis in order to sustain/control weak/negative magnetic shear plasmas. Thanks to this off-axis configuration, the current profile with weak or negative magnetic shear can be sustained coexisting with bootstrap currents in favour of steady state tokamak operation.

In the torus hall at the Naka site, the modification of the N-NBI system, a part of the construction work for JT-60SA, has been started to lower the beamline injection position by 0.6 m from the equatorial plane. In the modification, the present components of the ion source, the ion dump tank and the carbonated cell stand will be replaced with ones which were rebuilt last year. All the modifications will be completed around this December. In order to allow this work, the maintenance stage around the beamline is now being removed.

News

Error field correction coils promising for ELM control

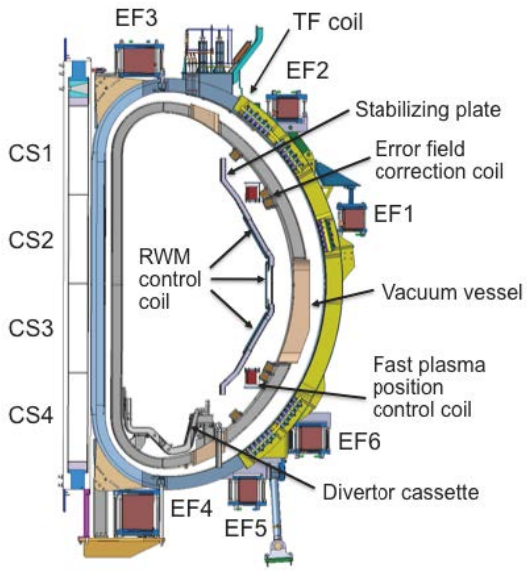


Figure 1: Cross section of the JT-60SA tokamak

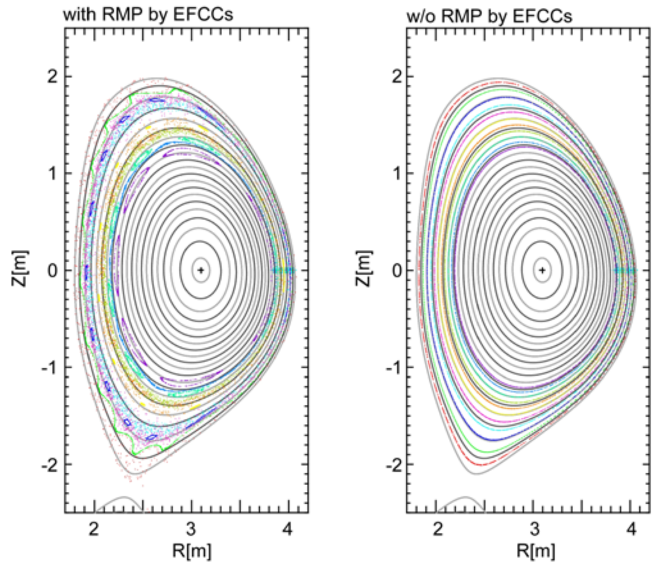


Figure 2: Magnetic field line tracing with RMP (on the left) and without RMP (on the right)

JT-60SA will exploit MHD stability control, in particular at high beta, using a combination of the stabilising plates, fast plasma position control coils (FPCC), error field correction coils (EFCC), and resistive wall mode control coils (RWMC) (Figure 1). The EFCCs (3-poloidal x 6-toroidal, 30 kAT each) are primarily used for minimisation of error fields due to manufacture and assembly errors of the toroidal and poloidal field coils and the neutral beam correction coils. The error fields must be reduced in order to enlarge the field-null area sufficiently around the plasma centre at the discharge break down and to avoid occurrence of locked mode instabilities during a plasma current ramp-up.

The EFCCs can be also utilised for producing resonant magnetic perturbation (RMP) which is generally considered useful for stabilising edge localised modes (ELMs) for H-mode plasmas. For a JT-60SA plasma, three-dimensional magnetic field line tracing was carried out by following field lines around the torus 500 times to evaluate whether RMPs controlled by EFCCs can be used for ELM control.

Without RMP (Figure 2 right), the traces of the magnetic field line go round on the magnetic surface (solid line) obtained by the equilibrium calculation, showing that the magnetic field lines are almost converged on the magnetic surface. By contrast, when the EFCC (Figure 2 left) is applied, the traces of the magnetic field line largely intersect the magnetic surfaces in the peripheral region, showing that the magnetic field lines become stochastic as required for ELM control.

In future, the calculation accuracy is planned to be verified, and a quantitative index such as the connection length will be introduced into the analysis.

Meetings

15th magnet power supply Design Review Meeting

The 15th magnet power supply Design Review Meeting (DRM) on the switching network units (SNU) for the central solenoids of JT-60SA was held by videoconference on 25 June 2013 with attendance of 16 experts from Germany (Fusion for Energy Garching), Italy (ENEA Frascati and OCEM Energy Technology Bologna) and Japan (JAEA Naka).

The main topic of the DRM consisted of the discussion of the first design report (FDR). The draft version of the FDR was prepared by OCEM after discussion with ENEA for a month.

At the beginning of this meeting, A. Cucchiaro, ENEA greeted the participants and introduced the activities. A. Lampasi, ENEA and L. Novello, F4E expressed their satisfaction with the good job done so far by OCEM.

There were lots of discussions on the comments made by ENEA, F4E and JAEA about cable connection, IGCT (integrated gate-commutated thyristor stack, SCB (static circuit breaker) diagram, auxiliary AC power, semiconductor pre-selection, thermal dissipation scenarios and fault analysis.

The final version of the FDR would be uploaded by ENEA in the DMS in a couple of weeks.

Calendar

September 16-20, 2013
11th International Symposium on Fusion Nuclear Technology (ISFNT-11)
Barcelona, Spain

October 9, 2013
13th Meeting of the STP Project Committee (PC-13)
Naka, Japan

October 23-24, 2013
18th Technical Coordination Meeting (TCM-18)
Naka, Japan

December 17, 2013
13th Meeting of the BA Steering Committee (SC-13)
Saclay, France

Contact Us

The JT-60SA Newsletter is released monthly by the JT-60SA Project Team.
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For more information please visit the website: http://www.jt60sa.org/