Integrated Operation Scenarios (IOS)

Report of activities in 2012

G. Sips (chair), T. Luce (deputy-chair), J. Snipes (IO deputy-chair)

Summary of the2 meetings held in 2012

IOS-TG meeting, 16-19 April 2012, CIEMAT, Madrid, Spain

IOS-TG Meeting, 15-18 October 2012, La Jolla, USA

(JET and JT-60U discharges) in preparation for JT-60SA simulations (using CRONOS and TOPICS).

Plasma control:
A WG was set-up ~1 year ago to help define the ITER control system physics requirements. The aim is to produce a document describing the physics requirements. Final reports are due by October 2012, in time for the PCS CDR (November 2012). Control areas include: Vessel conditioning techniques, Magnetic control (various) + sophisticated fault response controller. Core fuelling systems (gas introduction, pellets, diagnostics), first wall heat flux coverage (note the high % of visible and IR camera coverage), rotation control (more R&D is required in this area), ….and many more.

Coupled DINA-CH and CRONOS scenario simulations include tests if scenarios developed with free boundary stay inside PF limits (with control) when coupled with an equilibrium solver. The transport is computed by CRONOS and all magnetics (including q-profile) by DINA-CH. However SS-scenario simulations with 600.000 time steps takes 3 weeks CPU to finish.

Control of burning plasmas remains a topic of research. The main question is if simple controls on power density or other averaged parameters would be sufficient to control the burn. So far feed-forward simulations with ASTRA have tested variation in power, density and argon concentration. The work is on-going.

Use of the CS to control the plasma inductance is relevant and can be the basic control scheme for li, combined with additional actuators (like ECCD). Feedback of li with V-CS demonstrated. This control model should be used for ITER ramp down simulations.

SS scenarios and actuators:
A new model for NB shine-through was installed in NUBEAM, using excited neutrals and the ADAS library. NNBI with H/D/T species can be computed, and impurity species in the target plasma, but not yet W. Application to the pre-nuclear ITER discharges show only a 6% reduction in shine-through power.

Using off-axis NB, DIII-D observes a significant change in pitch angle was observed. The computed NBCD deposition profile is in very good agreement with classical modelling of the current drive.

The contribution of the alpha-power to the power required for the H-mode DT plasma has been studied in simulations of L-mode plasma confinement. Forcing the plasma to stay in L-mode (no pedestal) gives at low flow shear 10-15MW of alpha heating.

IAEA papers proposed by the IOS-TG are:

1. Multi-machine comparisons of divertor heat flux mitigation by radiative cooling A. Kallenbach et.al.
2. Development of ITER scenarios for pre-DT operations, T. Casper et.al.
3. Integrated Magnetic and Kinetic Control of Advanced Tokamak Scenarios on DIII-D Based on Data-Driven Models, D. Moreau et.al.
4. On the use of Lower Hybrid waves at ITER relevant density, A. Tuccillo et.al.
5. Demonstrating the ITER baseline operation at q_{95}=3, A.C.C. Sips et.al.

The work required was agreed and deadlines for the IAEA FEC were clarified.

IOS-TG Meeting, 15-18 October 2012, La Jolla, USA

Meeting date and Venue:
The second IOS –TG meeting in 2012 was held from 15 October to 18 October 2012 at the Marriot Hotel, La Jolla, USA. A total number of 35 people attended the meeting. The Chairs thank the hosts General Atomics, and in particular C. Greenfield for the good organisation and hospitality.

Actions from the previous meeting:
The actions for this meeting were reviewed. The discussion of the actions was followed by a detailed presentation on 1 of the actions regarding the NB shine-through calculations for helium and hydrogen plasmas in ITER based on model cross-section calculations that do not include excited states for helium or impurities. The first wall panels have some parts with high incidence angles and a maximum power load up to 4.7MW/m2. This will give a minimum density for using hydrogen NBI in He plasma of 2.7e19m-3, and for pure hydrogen 4.3e19m-3. Further work is required and it is proposed to open a joint activity on H-NBI injection modelling. The IOS-TG is concerned as to the margins for operation at 5-7MA.

ITER:
The status of ITER was given and discussed, including changes to the organisation, staffing, and focus on non-active operation with 63MW of heating. Changes to the CS as proposed by the US-DA, reduces the total flux by another 3Wb. Long pulse scenario modelling (10-15MA at low density) is progressing including EPED1/SOLPS models. Details of a paper in preparation were discussed. The Core-SOL modelling of L-H and H-L transitions in ITER is progressing using JINTRap7>> BDdiscue

strongly on wall conditions, prefill pressure, field null and injection angle. AUG obtains similar results. TS, FTU and KSTAR are still planning experiments.

For joint experiments on steady state and hybrid scenarios, assessing the beta limit for the ITER recommended q–profile has not progressed for years and will be stopped as joint experiment. The access conditions for SS and Hybrids use a database analysis to document the role of q-profile, power, shape, density, etc. From the analyses, new experiments are being proposed. Also AUG and MAST have collected new databases, to be merged with the DIII-D and JET data. MAST can access q-profiles with elevated core q values at the start of the heating and 136 discharges for the database (including the scenario development discharges) have been collected. The details of the trends were discussed.

The data for dedicated * scans for hybrid discharges in DIII-D and JET, have been reprocessed and validated. The proposed journal paper is progressing. AUG will do experiments in 2013 and a comparison with new JET data with the ILW is being considered.

For the collisionality scaling of hybrids, no dedicated shots were performed in 2012. Large databases have strong dependencies of * with *. Real experiments are needed. Some detailed analyses on DIII-D does show strong dependence of B on * at fixed *. Experiments have been proposed in 2013 for JET, DIII-D and AUG.

For ICRH coupling studies, the experiments do not show strong evidence for direct ionisation near the antenna (no extra density in measured profiles). JET, AUG, DIII-D and KSTAR see some local effects, TS sees no evidence for local effect at all. The effect of puffing on confinement needs to be documented. So far the application of power has little effect on SOL density profiles.

The (lack-of) LH CD at high density was reviewed in an IAEA paper by A. Tuccillo. A NF paper is planned. Cross modelling (codes of 1 group applied to data of others) of the data is progressing very well. New results from EAST using 2.54GHz showing reduced CD at higher density. There is a lot of discussion of the LH experts on the interpretation of probe data.

Specific discussion session: Seeding and plasma termination:
A special discussion session was organised on seeding and plasma termination (following a paper by A. Kallenbach at the IAEA):

The results from AUG were discussed in detail for ECRH X3 and ICRH core heating at q_{95}~3. Compared to a carbon reference pulse, the $_N$ in the W discharge is higher ($_N$=2.2 vs $_N$=1.8). Similar to JET, H_{98} increases with $_N$ (and stronger compared to carbon). New experiments should include lower heating power and N2 seeding at q_{95}~3. Simultaneous Ar (main chamber) and N2 (divertor) seeding has been very successful at AUG. In DIII-D a puff and pump method is used to create a radiative mantle. The dependence on gradB drift was studied. With increasing argon dosing rate, the core radi

prediction would give similar 0.1MA/MW efficiency, so 50MW can drive 4-5MA. A travelling wave antenna could couple 600-800MHz in ITER.

An overview of the EC system in ITER was given by M. Henderson. The EC system in ITER has many functions, from burn-through, ramp-up, burn, MHD control and ramp down. The EL

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5 papers at the FEC in San Diego, 2012

1. Multi-