REAL-TIME PROTECTION OF IN-VESSEL COMPONENTS IN ASDEX UPGRADE

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Safe operation of ASDEX Upgrade (AUG) needs a protection of in-vessel components against overheating mainly due to two reasons. (i) The available heating power of up to 20 MW neutral beam heating and 8 MW of wave heating allows experiments with an ITER relevant P_{heat}/R_{maj} of about 17 MW/m. The resulting divertor power load in combination with pulse lengths of 5-10 s exceeds the divertor energy limit of about 20 MJ. The corresponding ELM averaged peak heat load can be well above 10 MW/m^2 resulting in target temperatures above 2000°C for long pulses. (ii) The evolution of AUG from a carbon to a full tungsten experiment was finished in 2007 with the installation of graphite divertor plates coated with 200 µm tungsten. These coated graphite tiles were qualified for an ELM averaged cyclic load of 10 MW/m^2 and single events up to 23 MW/m^2. Exceeding these limits resulted in a delamination of the tungsten coating and eventually a disruption of the discharge.

The video real-time system (VRT) for machine protection is based on CCD/CMOS cameras installed in different ports of AUG covering nearly the whole in-vessel surface. A visible-system instead of ir-systems is cheaper and less sensitive against changes of optical parameters like emissivity of the target and transmission losses. This behavior results from the strong temperature dependence of the Plank function in the visible wavelength region that in turn requires a comparator like operation.

The main concept of the present system originated in 2007 and is based on the experience with a MS-Windows system with four cameras. Matrox Morphis frame grabber cards are used to digitize 12 analog video signals. Four Xeon Paxville 7030 MP microprocessors running at 2.8 GHz with dual core and hyper-threading technology offer 16 virtual CPUs. Each of the three Morphis frame grabber cards is assigned to one CPU for interrupt handling.

For each camera a maximum of 16 regions of interest (ROI) can be assigned. Position, size and shape of the ROIs can be defined free and independent and are linked to a protection algorithm.

At present, two algorithms are implemented. If the location of a likely overheating is known in position and size, a ROI is assigned to this subframe and the integrated intensity is calculated. This algorithm is preferentially used to protect movable probes or parts of the outboard limiters that are in danger of overheating during certain phases of the discharge. The second algorithm was implemented to detect hot spots in a larger ROI, e.g. local overheating of parts of the divertor whereas the divertor itself is defined as a single ROI. Here, the algorithm searches for the brightest 3x3 pixel square. Together with previous median filtering the latter prevents false positives caused by the interaction of neutrons with the CCD detector. In addition to the selection of the active algorithm for each ROI 4 levels of reaction can be defined. At the moment the highest level is used to terminate the discharge by a soft pulse stop. But other actions are in preparation, e.g. the reduction of the heating power or the application of nitrogen seeding to increase the fraction of radiation and to reduce the divertor heat load.

The paper will discuss the advantages and disadvantages of a machine protection system based on video cameras compared to infrared cameras. In addition, the hard and software and its interaction with the CODAC system will be described. Examples for the action of the VRT will be presented and its reliability will be discussed.