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A NETWORK-BASED TELEMETRY UPGRADE FOR THE DIII–D NEUTRAL BEAM POWER DIAGNOSTICS

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Water flow calorimetry is utilized at DIII-D to quantify injected neutral beam power. As part of the system upgrades for the past year, the old CAMAC-based telemetry system for the WFC diagnostic was replaced by a fiber optic Ethernet-based telemetry system. The difficulty to obtain replacement CAMAC hardware and the prospect of lower noise and spurious signal sensitivity motivated the move to fiber optic Ethernet-based telemetry. The new system was installed and tested during the 2006 physics campaign startup phase. Both the CAMAC-based system and the new Ethernet-based system were used to acquire data from one common neutral beam ion source in the current year. System performance improvements are presented.

INTRODUCTION

In conjunction with the recent rotation of the 210 deg neutral beamline [1] on the DIII-D tokamak, the telemetry for the water flow calorimetry (WFC) system on all the beamlines was upgraded. The old system relied on a dedicated CAMAC highway, and over time it became difficult to repair or replace CAMAC components as CAMAC vendors dwindled. The old system also exhibited spurious signal pickup that was indicative of aging components.

WFC measures the power deposition onto the beamline components such as the ion bending magnet pole shields and the beam dump calorimeter of each neutral beam ion source by recording the change in the cooling water temperature in the beamline components until that beamline component equilibrates back to ambient temperature after a beam shot of known duration. The measured power is very sensitive to spurious signals on the measured component coolant water temperature. The old telemetry consisted of a dedicated CAMAC highway that digitized thermister stack (ΔT block) output voltages for storage and analyses. Triggering was provided to the CAMAC system by a +5V TTL “beam on” output signal generated by the beam control computers, which were continuously polled by a look-at-me (LAM) module in the CAMAC controller crate.

Spurious signal pickup was possible in this system from damage in the grounding shield of 10 to 20 m long twisted pair wires that connected the ΔT blocks to the Transiac [2] digitizer/amplifier modules, multiple ground paths between the beamlines and the CAMAC racks, and spurious “beam on” signals from the hardware trigger circuitry.

The replacement telemetry system was designed to be less prone to hardware malfunctions, easier to service, and less sensitive to spurious signal pickup. A fiber optic Ethernet-based acquisition system with data acquisition (DAQ) modules from Sensoray [3] was selected to replace the CAMAC systems. The dedicated fiber optic Ethernet network addressed the concerns for voltage isolation and spurious signals abatement. The Sensoray DAQ modules (models 2601 and 2608) were chosen because they offered low noise digitization and low component cost. A block diagram of the Ethernet telemetry system is given in Fig. 1.

In the new acquisition telemetry; the ΔT block output voltages are conducted via twisted pair wires of 3-5 m lengths to the Sensoray modules. The DAQ modules digitize and condition the raw ΔT block output. The digitized signals are uploaded to the dedicated fiber optic network by media converters, which convert the output voltage signals to light pulses at each beamline.

The WFC acquisition and analysis PC is connected to two Ethernet networks; a dedicated fiber optic highway for the digitized ΔT output signals and the main DIII-D Ethernet highway. The WFC PC continuously polls the DIII-D highway for the beam triggering information. An acquisition begins when the WFC PC receives a beam trigger from the beam computers via a transmission control protocol (TCP) socket write. A WFC acquisition comprise of a timed Sensoray module read on the dedicated fiber optic highway. The acquired ΔT data are stored onboard the WFC PC, and after the timed acquisition the WFC PC reads the post beam shot data (beam on-time, actual beam voltage, actual beam current) from the network mounted data base for that shot. Using the post shot information, a LabView [4] virtual instrument module computes power flow accountability for that beam shot.

A TCP socket-based acquisition triggering module, a TCP-based post shot information retrieval module and an acquisition interface module were developed in the

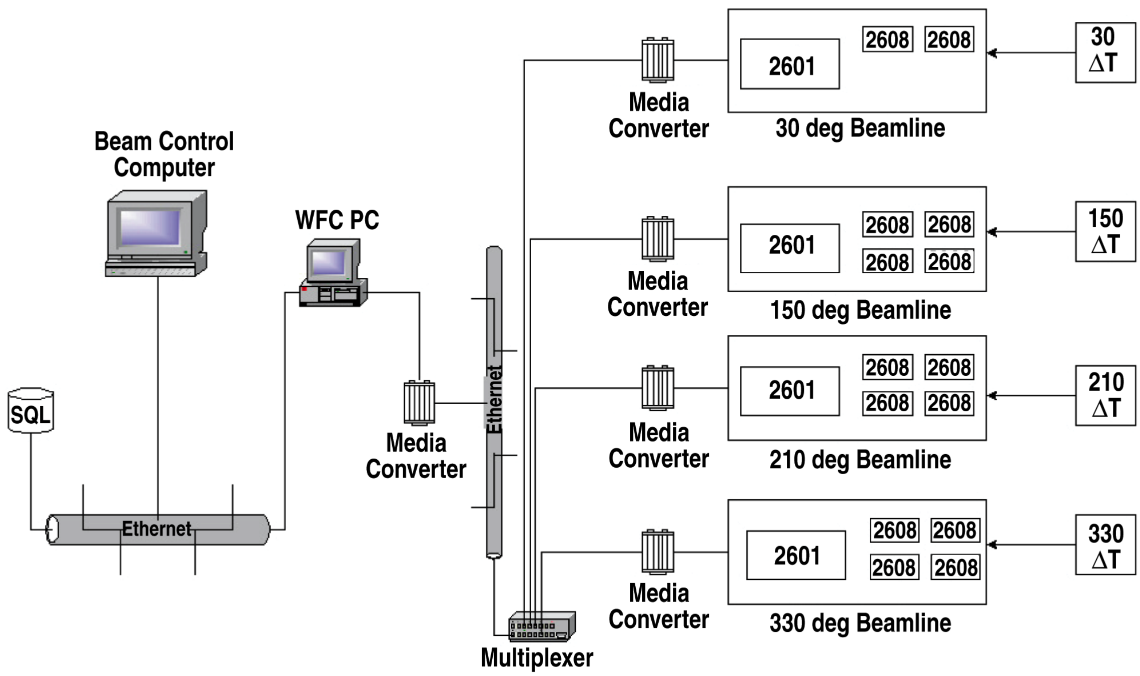

Fig. 1. Block diagram of the water flow calorimetry telemetry system.

LabView environment to support this telemetry upgrade. The acquisition interface module accesses the Sensoray DAQ modules by calling vendor supplied TCP protocols with dedicated C++ routines developed at GA which interface with the LabView environment through code interface nodes.

ACCEPTANCE TEST

The new telemetry system was designed to be more robust, easily serviceable, and have better noise and spurious signal rejection than the CAMAC system. The ease of installation confirmed the serviceability of the new telemetry hardware. The robustness of the telemetry system can only be observed over a period of years.

First, to quantify the performance of the new system, a series of measurements were taken with each system to quantify the beam transmission efficiency, which is only dependent on the ion source conditions of the selected neutral beam. Figure 2 is a plot of the measured transmission efficiency data from both telemetry systems overlaid as a function of the beam optics parameter, k. The measured data reported by both the CAMAC and Sensoray-based telemetry systems are within the experimental error of 3.5% of the measured value; which is a function of ΔT block sensitivity, precision in water flow rate measurement, and variance in the cooling water baseline temperature. These data give confidence that the data acquired are consistent with the neutral beam ion source conditions and not biased by the telemetry hardware.

The spurious signal pickup of each system was quantified by taking two sets of data, with both the CAMAC telemetry and the Sensoray telemetry systems. The first set of data looked at the effect of DIII-D's magnetic fields on the telemetry systems by firing the beam ion source into the beam dump calorimeter asynchronously with the DIII-D plasma. This ensured that at some point during the 600 s of WFC acquisition time after the "beam on" trigger, there would be a DIII-D plasma shot. The ion source operating parameters for these measurements were fixed at optimum beam optics. For each beam shot; the ion source was commanded to produce a 75 kV beam of 1.5 s

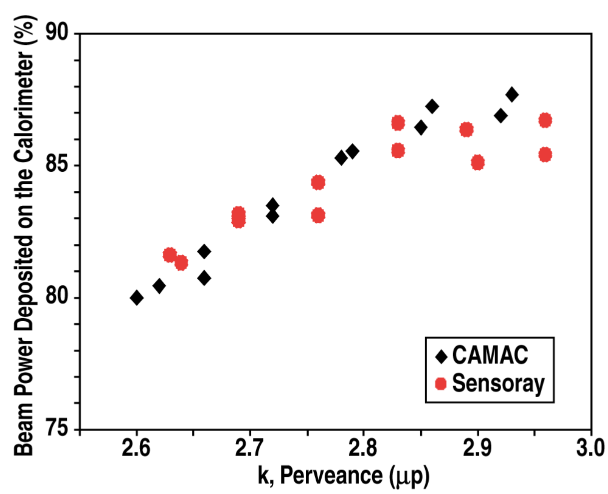

Fig. 2. The measured transmission efficiency.

duration. The ion bending magnet was not energized for these data, so that the effects of the ion bending magnet on spurious signals can be separated from DIII-D's contribution. Both telemetry systems looked at five beam shots each to quantify the combined ion and neutral particle power delivered to the beam dump calorimeter. The results of this first set of measurements are presented in Figs. 3, 4 and 5.

The second set of measurements simulated beam injection into the DIII-D plasma in which the ion bending magnet is energized to sweep the residual energetic ions out of the beam path into the beam ion dump. During a beam injection shot, energizing the ion bending magnet keeps the residual ions from being injected into the DIII-D vessel. For each telemetry system, five shots were taken with the ion bending magnet energized to quantify the effects of the ion bending magnet on spurious signal pickup in the telemetry. The results are presented in Figs. 6, 7 and 8.

RESULTS

Figure 3 presents the averaged power flow accountability for both telemetry systems when the ion bending magnet is not energized. The averaged power flow accountability is the sum of the beam power deposited onto the instrumented beamline components, averaged over the five beam shots taken with each telemetry system. There are 10 components in the beamline that are instrumented with WFC. Of these 10 components only the source collimator, neutralizer collimator, and calorimeter beam dump see significant power deposition during a beam shot into the beam dump calorimeter when the ion bending magnet is not energized. The bulk of the beam power is deposited onto the calorimeter, which intercepts the beam when the beam is not injected into the DIII-D vessel. These data are very consistent from shot to shot. The Sensoray telemetry reports systematically lower measured power numbers; CAMAC reports 97.6% of theoretical power versus 95.6% of theoretical power reported by the Sensoray telemetry.

The beamline components that see significant power during a beam shot with the ion bending magnet energized are the source collimator, the neutralizer collimator, the magnet entrance collimator, the magnet pole shields, the calorimeter, the magnet exit collimator and the ion dump.

The power flow accountability for the two telemetry systems with the ion bending magnet energized show a variance between the two systems: CAMAC reports 98.6% of theoretical power versus 92.6% of theoretical power reported by the Sensoray telemetry. This discrepancy is subject to further examination in the next physics campaign.

Representative data for both ion bending magnet conditions are presented in the following four figures to catalog spurious signal pickup. Data for the magnet pole shields and the beam dump calorimeter are selected. Spurious signal sensitivity is highlighted by plotting data from both telemetry systems overlaid.

Figure 4 is a plot of the measured ΔT data for the beam dump calorimeter. The power deposition to a component is measured by integrating the change of the coolant temperature over the acquisition period. The plot of the ΔT measurement over time is indicative of the energy removed from the component by the coolant over time. The CAMAC telemetry reports a slightly higher ΔT measurement during the initial 200 s of the acquisition. It also shows that the CAMAC system picks up spurious outlier data points.

Minimal power is expected to be deposited onto the magnet pole shields when the ion bending magnet is not energized, when the beam ion source is operated at optimal optics, so a small temperature rise that decays quickly is expected for the pole shields. Figure 5 indicates that with the ion bending magnet not energized, the Sensoray telemetry reports trace temperature rise in the magnet pole shields as expected. The CAMAC data indicates the existence of an elevated temperature baseline. The Sensoray data correlates well with the expected behavior for the pole shield measurement.

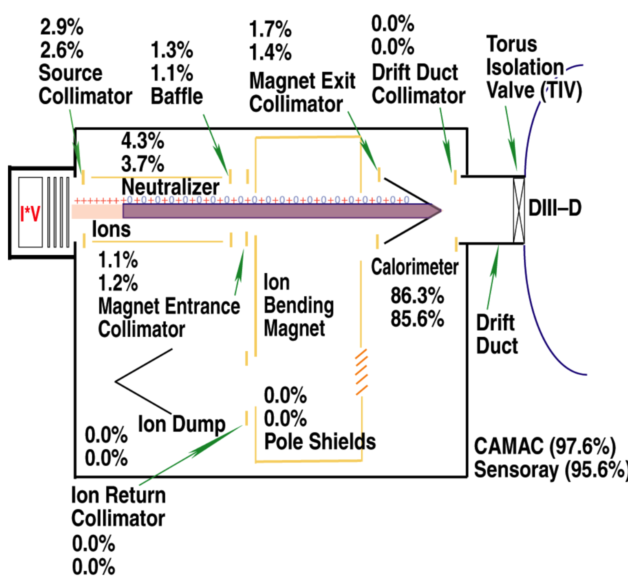

Fig. 3. Power flow accountability comparison ion bending magnet not energized.

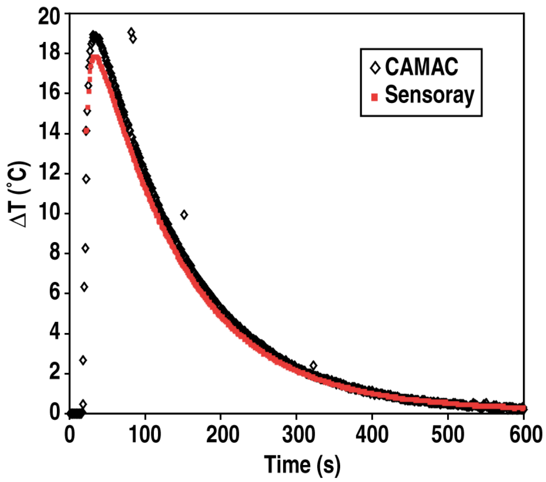

Fig. 4. ΔT data for the beam dump calorimeter with ion bending magnet not energized.

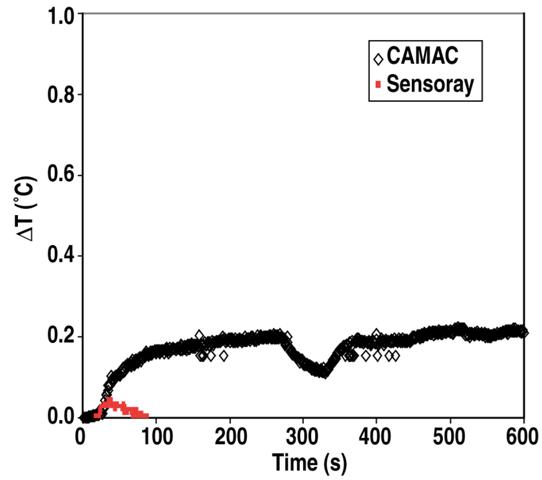

Fig. 5. ΔT data for the pole shields with the ion bending magnet not energized.

Figures 6 and 7, respectively, present representative data for the calorimeter and the magnet pole shields when the ion bending magnet is energized. Both data sets confirm that the ΔT data for the CAMAC telemetry consistently shows a higher peak temperature and a tendency to pickup spurious data fluctuations during the acquisition period. All these acquisitions were taken asynchronously with DIII-D plasma operation in the acquisition period. The Sensoray data exhibit no pickup of spurious data fluctuations.

The variance in the power accountability reported by the two telemetry systems when the ion bending magnet is energized presented in Fig. 8 is under study. The components that show significant difference in power deposition are the ion dump (17.0% versus 15%) and the pole shields (11.7% versus 10.4%). The sum of the difference for the power deposition for the two components is 3.3%. If the difference for these two components did not exist, the CAMAC and Sensoray reported power accountability would be within the bounds of measurement error. These two components are most affected when the ion bending magnet is energized. An elevated temperature baseline was reported by the CAMAC system for the pole shields in Fig. 5. Figure 9 is representative data for the ion dump when the ion bending magnet is not energized.

The ion dump also exhibits a non-zero baseline temperature throughout the acquisition period. These data suggest that the CAMAC telemetry for all the other components may also have baseline offsets that are affected by energizing the ion bending magnet.

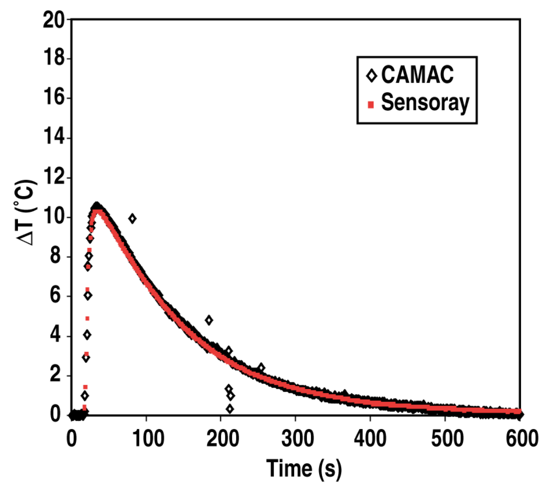

Fig. 6. ΔT data for the beam dump calorimeter with ion bending magnet energized.

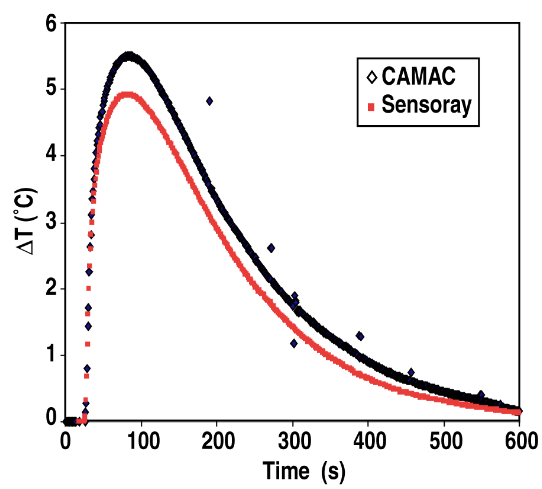

Fig. 7. ΔT data for the pole shields with the ion bending magnet energized.

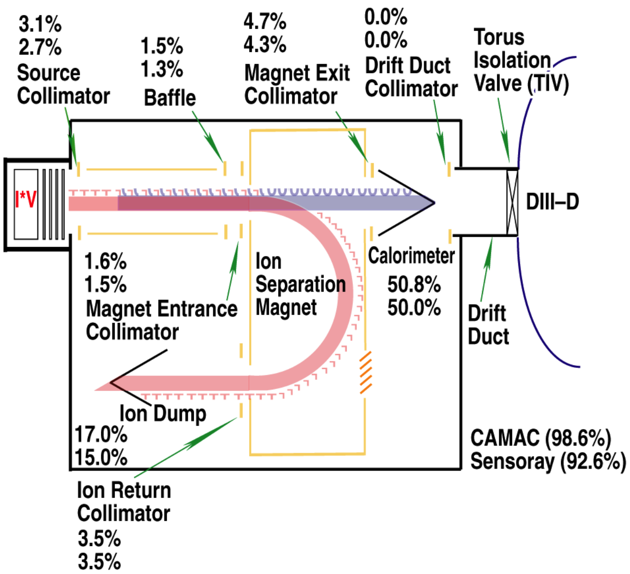

Fig. 8. Power flow accountability comparison with ion bending magnet energized.

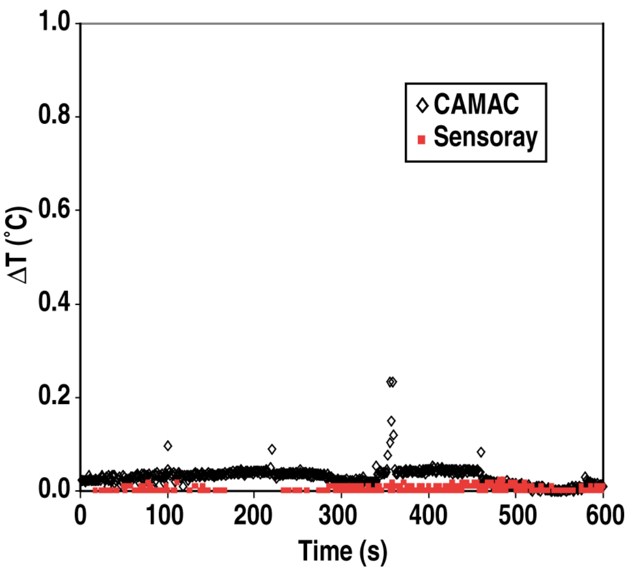

Fig. 9. ΔT data for the ion dump with the ion bending magnet not energized.

CONCLUSIONS

A new Ethernet-based telemetry system for measuring beam power was installed on the neutral beam systems of DIII-D. In-situ side-by-side testing of the new system indicates that it is less prone to pick up spurious data fluctuations than the old CAMAC-based system. The new Ethernet-based telemetry system and the old CAMAC-based telemetry system measured beam power flow accountability to within the margin of measurement error when the ion bending magnet is not energized. A variance in power accountability arises when the ion bending magnet is energized, with the bulk of the difference concentrated in the two components most affected by the ion bending magnet. Further study will be necessary to fully understand the mechanism for this observed effect.

It is expected that the new telemetry system will be easier to service based on the experience gained during system installation. Performance of the Ethernet-based telemetry components over long periods of D-T neutron exposure is to be determined. The widespread availability of such components for the foreseeable future gives confidence that replacement components will remain available on a cost effective basis.

ACKNOWLEDGMENTS

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