Development of Data Acquisition Software for Ultrasonic Inspection of Reactor Pressure Vessel Weld Joints in Boiling Water Reactors

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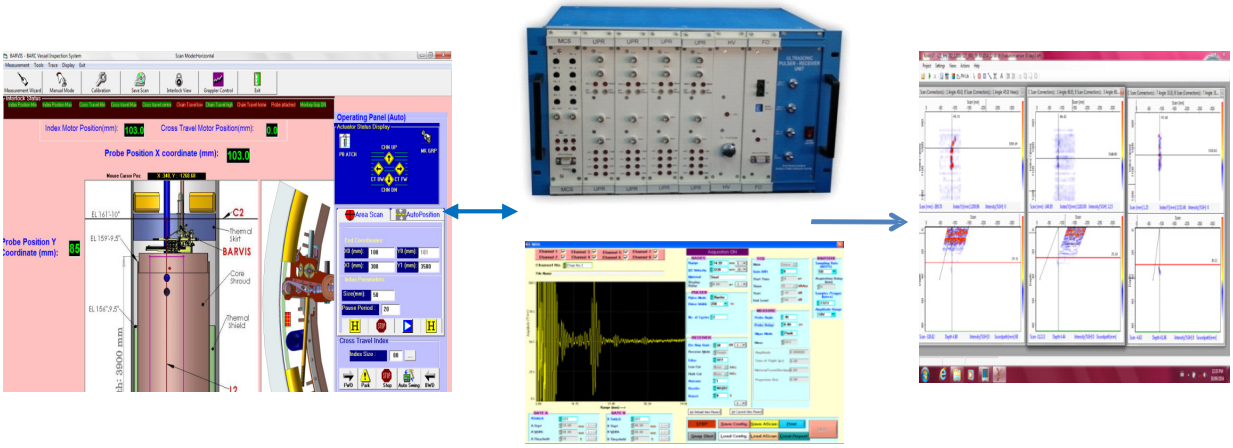
Abstract

Tarapur Atomic Power Station (TAPS-1&2) has completed 46 years of successful operation. It is mandatory to inspect the Reactor Pressure Vessel (RPV) welds of these two reactors at regular intervals for detection and characterization of flaws as per the regulatory requirements. Windows based system software has been developed at Electronics division, BARC for control & data acquisition from an indigenously developed 8-channel Ultrasonic Testing (UT) system for In-Service Inspection (ISI) of RPV weld joints at TAPS-1&2. The software controls various Pulser/Receiver/Digitizer parameters of the 8-channel UT system, named ULTVIS, and acquires position encoded C-scan data from the system in either comb or meander pattern. It provides A-scan panel for calibration purpose & saving of channel related configuration data files, C-scan panel for configuring area scan parameters and display of each B-scan buildup while acquiring the C-scan data. It interfaces with two different mechanical scanners to cover different regions of RPV. The software was tested with a mock-up facility and then deployed successfully for ISI of RPV weld joints at TAPS. A file splitter utility to split the file, channel-wise or depth-wise, has been developed for easy analysis of the acquired C-scan data. Also a band pass filter with user programmable frequency bands has been implemented to facilitate removal of random noise from the acquired data when amplifier with very high gain is used. Due to high radiation environment inside the reactor, it is not possible to use potentiometer or encoder for position measurements. To overcome this issue, a UT based position sensing mechanism has been envisaged. This software provides facility for position measurement using the UT technique while acquiring the C-scan data. This paper describes in detail various features of the control and data acquisition software developed at Electronics Division, BARC.

Keywords: Ultrasonic Testing, C-scan data acquisition software, Reactor Pressure Vessel, In-Service Inspection.

Introduction:

An automated UT based RPV inspection system has been developed indigenously to carry out In-Service Inspection (ISI) of RPV weld joints at TAPS-1&2. The system comprises of three major components: an automated mechanical manipulator (WIM2-M & BARVIS developed by RTD, BARC) carrying the ultrasonic probes; multi channel ultrasonic data acquisition system (ULTVIS - developed by Electronics Division, BARC) and data analysis software (developed by M/s. Lucid, Chennai) as shown in Fig. 1.



Automated Mechanical Scanner (WIM2-M & BARVIS), Developed by RTD, BARC

8-Channel UT Data Acquisition System (ULTVIS), Developed by Electronics Division, BARC

Data Analysis Software (KOVID), Developed by M/s. Lucid Pvt. Ltd., Chennai

Fig. 1 Major components of UT based RPV inspection system

The RPV inspection system employs eight ultrasonic transducers (45°, -45°, 60°, -60°, 70°, -70°, 0° Normal Beam and 0° Dual) for inspection of welds and parent metal. The data acquisition system, named Ultrasonic Vessel Inspection System (ULTVIS), acquires data from all the 8 transducers as well as positional information of the probe holder while the manipulator carrying the probe holder is in motion. ULTVIS saves the C-scan data in pre-defined file format which is understood by the analysis software. ULTVIS comprises of in-house developed 8-channel ultrasonic Pulser-receiver, digitizer, GUI based control & C-scan data acquisition software and potentiometer & encoder interface. The integrated system has been successfully tested at an underwater mock-up facility and subsequently deployed at TAPS. Consequent to the development of this automated RPV inspection system, the data acquisition time as well as the analysis time and efforts have been reduced drastically as compared to the earlier campaigns.

ULTVIS System and Role of Control & Data Acquisition Software:

The ULTVIS system [3] comprises of a) in-house developed 8-channel Ultrasonic Pulser-Receiver (UPR) [1], b) digitizer, c) GUI based control & data acquisition software, d) potentiometer and encoder interface for sensing the position of the probe holder. The control & data acquisition software of ULTVIS is in central command to control and acquire ultrasonic data. Fig. 2 shows the role of the control & data acquisition software in the RPV inspection system.

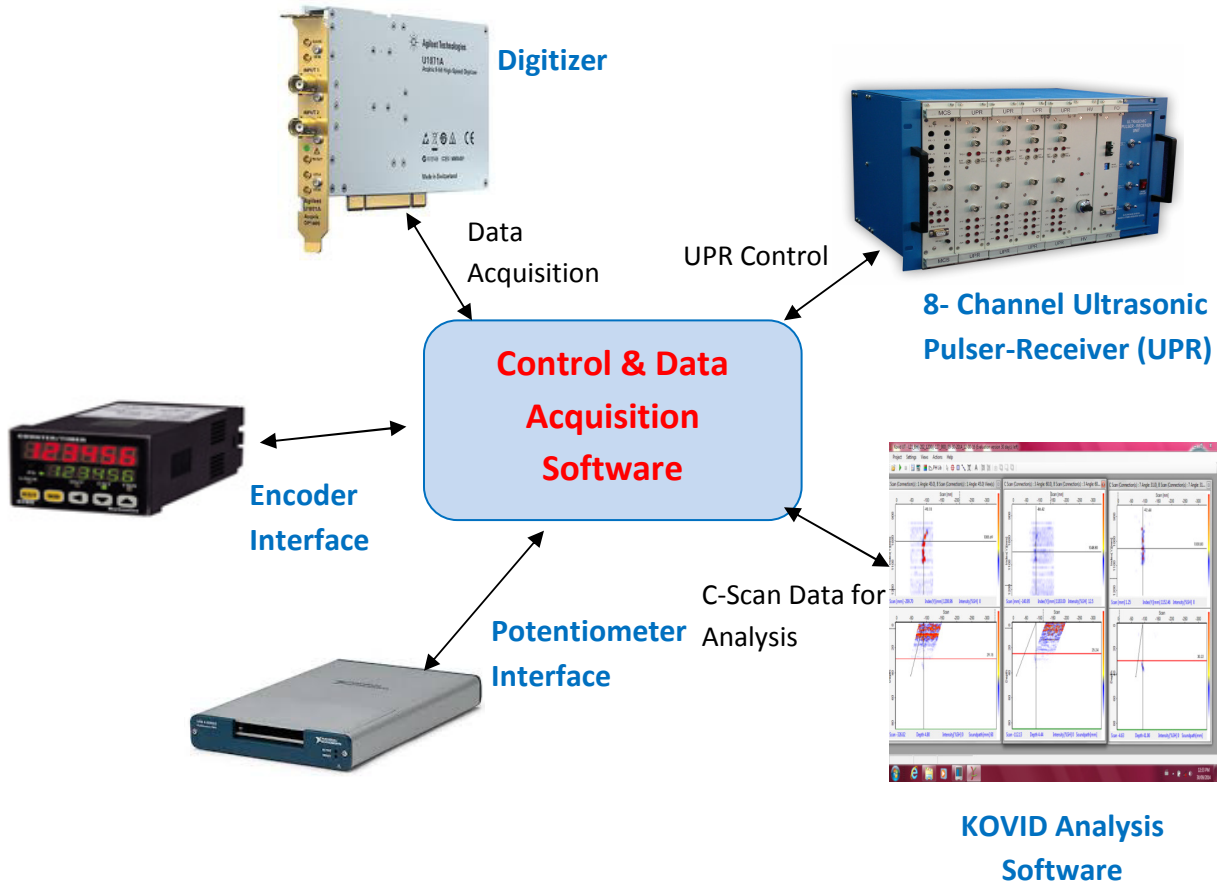


Fig. 2: Role of Control & Data Acquisition Software in RPV Inspection System

Specification of Control and C-scan Data Acquisition Software:

The control & data acquisition software is GUI based interactive software with following main features:

Data acquisition	: Sequential from 8-channels
UPR Control	: Using RS232 connection with predefined command format
Averaging	: upto 256 in A-scan
Display	: on line A-scan and B-scan
Display modes	: RF, Rectified (Full wave/ negative or positive half wave)
Digital filters	: FIR BP filter with controllable lower & upper frequency limits
Gates	: For calibration of probes
Measurements	: Peak/ Flank based
Scanner interface	: Potentiometer and encoder interface

Hand Shaking with Scanner Control Software:

The probe holder is moved by the scanner control software during C-scan data acquisition. Position data of the probe holder are acquired through potentiometer and encoder interface. Suitable handshaking has been provided between the data acquisition software and the scanner control software for synchronized data acquisition.

Description of Control & Data Acquisition Software:

On loading, the software checks for the presence of the Digitizer, UPR and Motor Connection with handshaking signals and informs operator about their availability by message pop-ups and checks on suitable boxes provided on the main panel (refer to Fig. 3). From the main panel, user may launch different panels and perform various tasks as explained below.

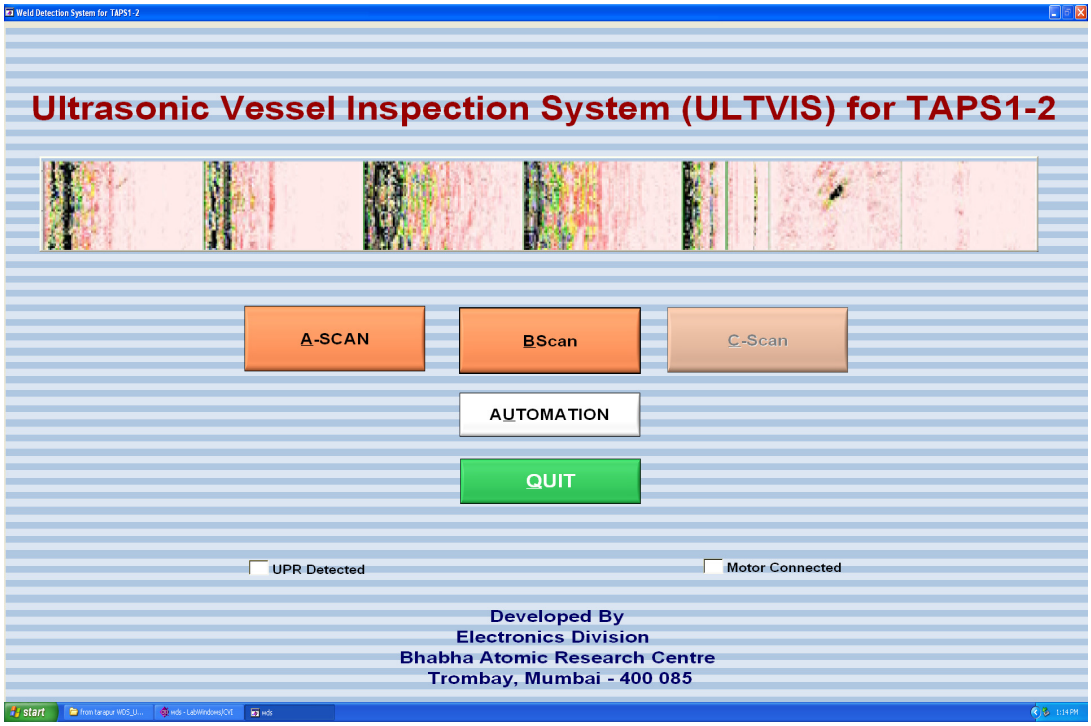


Fig. 3: ULTVIS Main Panel

1. A-Scan Panel for Calibration and Configuration of UPR with UT Probes:

Fig. 4 shows the screen shot of the A-Scan panel. This panel facilitates selection of active Channels; Basic parameters like Range, ultrasound velocity, Material; Pulser parameters like Pulse Mode, Pulse Width, No. of Cycles; Receiver Parameters like PreAmp Gain, Filter, Averages, Rectification; TCG parameters, Measurement parameters, and Digitizer Parameters. It provides online A-Scan display as well as measurements on the A-Scan waveform using 'Gates'. After setting of various parameters and calibration of selected channel, user can save all the configuration parameters in a file for future recall.

2. C-Scan Panel for Area Scan:

C-Scan panel shown in Fig. 5 is provided for configuring area scan parameters. After calibrating all the probes/ channels in the A-scan panel the user comes to this panel. Facility is provided to select Probe Holder and Scan Reference Weld. Depending on the selected probe holder Primary axis of movement, type of scanning (Meander or Comb), X-Axis interface and Y-Axis interface are programmed internally. Two types of probe holders are used: *horizontal* and *vertical*. For horizontal scanning meander type scan is used and for vertical scanning comb type scan is used. Current position of selected axis is displayed on the screen. Area to be scanned can

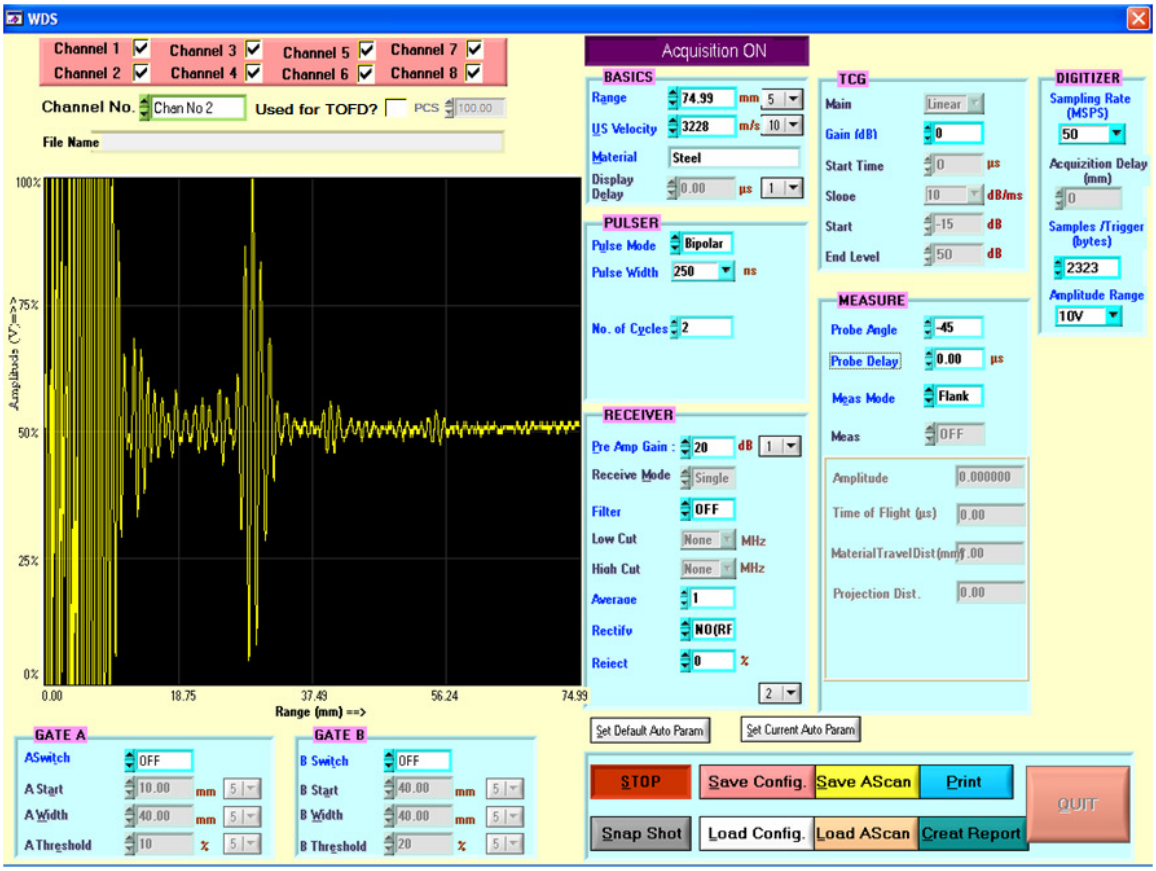


Fig. 4: A-Scan Panel

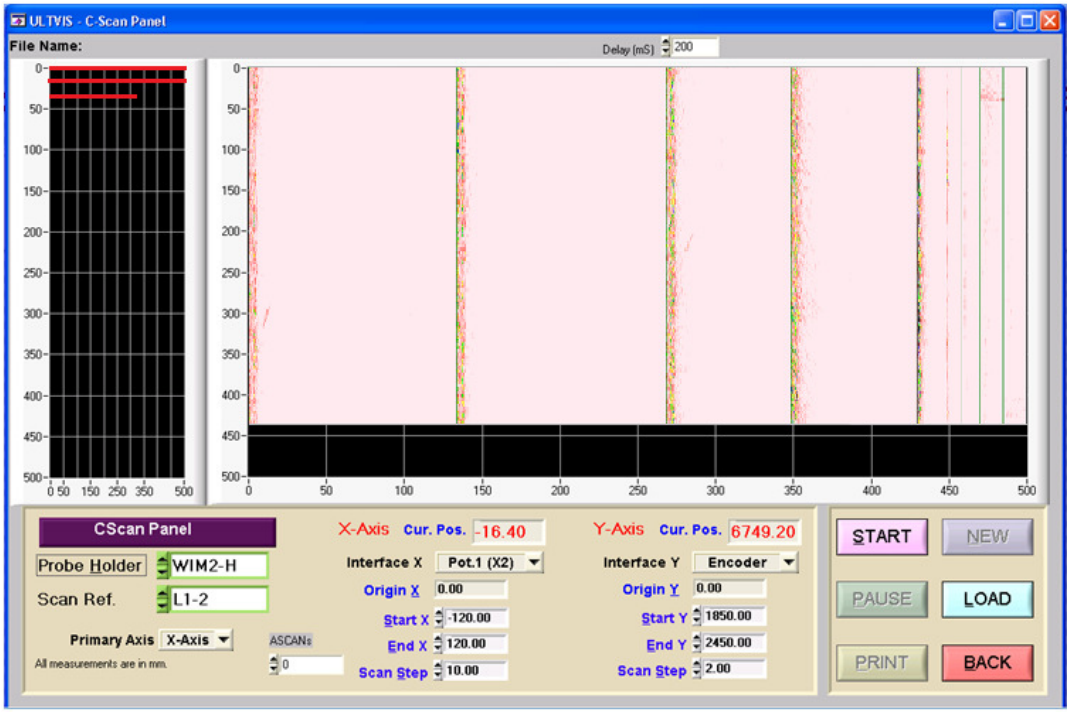


Fig. 5: C-Scan Panel

be selected by giving Start, End and Step values of X and Y axes. For operator convenience the file name for the C-scan data is either manual entry or automatically generated comprising of weld identification, probe holder, scanning direction (H:Horizontal or V:Verticle), start & end coordinates, date and time of scanning e.g. "***L21_BH(128_1200)(203_900)_09-30-2014_13-07-28.csn***". B-Scan image is displayed online for each location of index axis when the area scan is being taken. This helps in identifying any issues during the scan and then aborting the current scan, if required. Region covered is also displayed on the screen. The C-Scan data are stored in a pre-defined file format which can be understood by the KOVID analysis software. The pre-defined data file format includes *header* information (probe holder, probe, area scan, UPR, digitizer parameters) and A-scan raw data with corresponding position at each location of probe holder. The files thus saved can be opened in the KOVID environment and can be analyzed for flaw detection, sizing, report generation, merging of C-scan data etc.

3. B-Scan Panel for Review of Acquired Data:

B-Scan panel shown in Fig. 6 is provided for reviewing the acquire UT data from area scan. Here the user can open the B-scan image from the acquired C-scan data by selecting 'B-Scan' option from main panel. User can select the index axis location and view the corresponding B-scan on the screen. The displayed image contains B-scans corresponding to all the selected probes side by side. The image is displayed in pseudo colours using predefined colour palette.

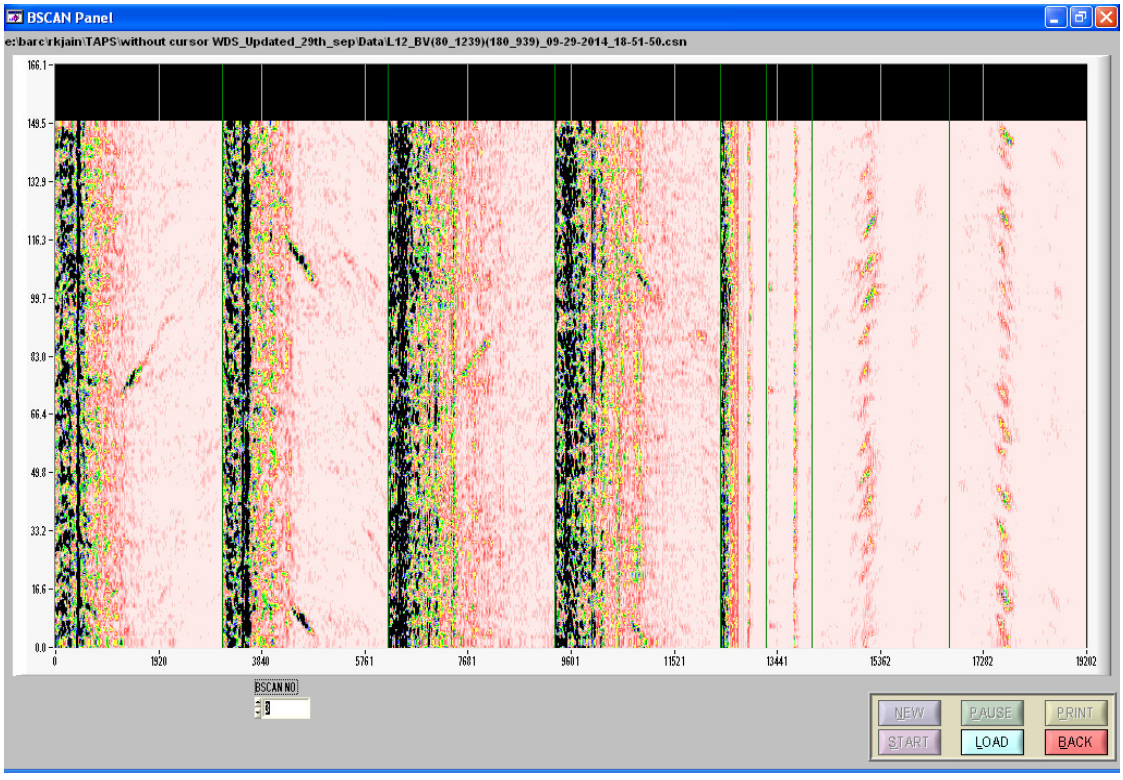


Fig. 6: B-Scan Panel

4. Filter and Splitter Utilities:

A band pass filter utility with user programmable frequency bands has been implemented to facilitate removal of random noise from the acquired data when amplifier with very high gain is

used (Refer to Fig. 7). A file splitter utility to split the file, channel-wise or depth-wise, has been developed for easy analysis of the acquired C-scan data. Fig. 8 shows screen print of Vertical Splitter utility for channel wise splitting of large C-Scan data files. Another Horizontal Utility is also developed to split the file depth wise. For example one has acquired data for 2000cm in a single area scan, then using this application, one can split files in equal size area scan viz. four files of 500cm each or five files of 400cm each or so on.

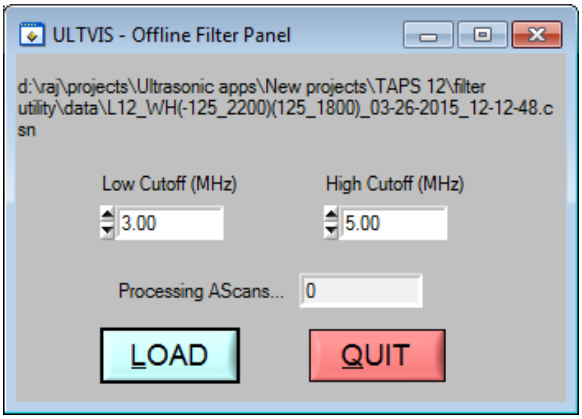


Fig. 7: Offline Filter Utility

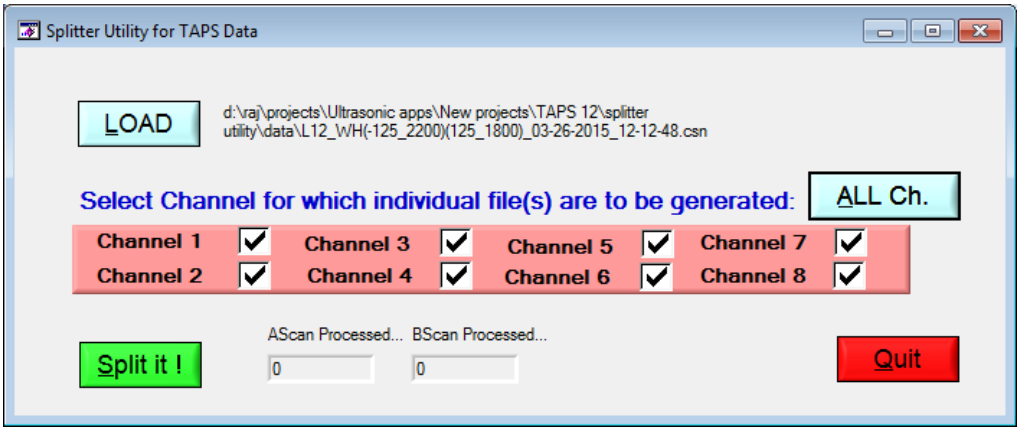


Fig. 8: Vertical Splitter Utility

5. UT Based Position Sensing:

Due to high radiation environment inside the reactor, it is not possible to use potentiometer or encoder in all the regions of reactor for position measurements. To overcome this issue, a UT based position sensing mechanism has been envisaged for some axes. The data acquisition software provides facility for position measurement using the UT technique while acquiring the C-scan data. This feature has been implemented and is under testing at the time of writing this paper.

Testing, Qualification and Deployment of Software

The control & data acquisition software was developed, tested and qualified with a mock-up facility at TAPS in the integrated RPV inspection system comprising of BARVIS manipulator,

ULTVIS and KOVID analysis software. Subsequently it was successfully deployed for the actual ISI of the RPV inspection at TAPS upper shell region. C-scan data files were generated which were analyzed successfully using KOVID.

Conclusion

Windows based system software has been developed at Electronics division, BARC for control & data acquisition from an indigenously developed 8-channel Ultrasonic Testing (UT) system for In-Service Inspection (ISI) of RPV weld joints in Boiling Water Reactors e.g. TAPS-1&2. The software controls parameters of the UT system, interfaces with control software of the mechanical manipulator carrying 8 ultrasonic probes, acquires position encoded C-scan data from the system in either comb or meander pattern while the probe holder moves continuously. It saves the data and each probe holder position in a predefined file format. This file can be analyzed by KOVID analysis software. The software was qualified using a mock-up facility at TAPS and subsequently it has been deployed successfully for ISI of some of RPV weld joints at TAPS.

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