the ENERGY lab

PROJECT FACTS

Advanced Research

Development and Implementation of 3-D, High-speed Tomography for Imaging Large-scale, Cold-flow Circulating Fluidized Bed

Description

The Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has a mission to improve the efficiency, reliability, and environmental performance of coal-fueled power-generation systems. As part of this mission, NETL's Advanced Research program has selected Tech4Imaging, with collaboration from The Ohio State University (OSU), to develop an imaging system for large-scale, cold-flow circulating fluidized beds (CFB).

The inherently complex nature of multiphase flows such as those encountered in fluidized beds requires a multi-dimensional measurement technique capable of providing real-time monitoring of the process dynamics and physical properties. A three-dimensional (3-D) high-speed electrical capacitance volume tomography (ECVT) system will be developed and demonstrated in this three-year effort. The ECVT uses simple equipment and high-level computing to render 3-D images directly from the measured capacitance data of multiphase flow systems.

Conventional Electrical Capacitance Tomography (ECT) using capacitance sensors for imaging multi-phase flow requires sensors large enough to pick up a signal. For uses where sensor size is limited, capacitance sensors can only be used for two dimensional (2-D) imaging. Acquiring 3-D images requires distribution of the sensors in three dimensions. In ECVT, changes in the sensor shape provide 3-D characteristics so that 3-D imaging can be obtained despite the limitation on capacitance sensor size. In the past, this approach led to a highly non-linear image reconstruction problem that was difficult to solve. Tech4Imaging has developed

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PERIOD OF PERFORMANCE

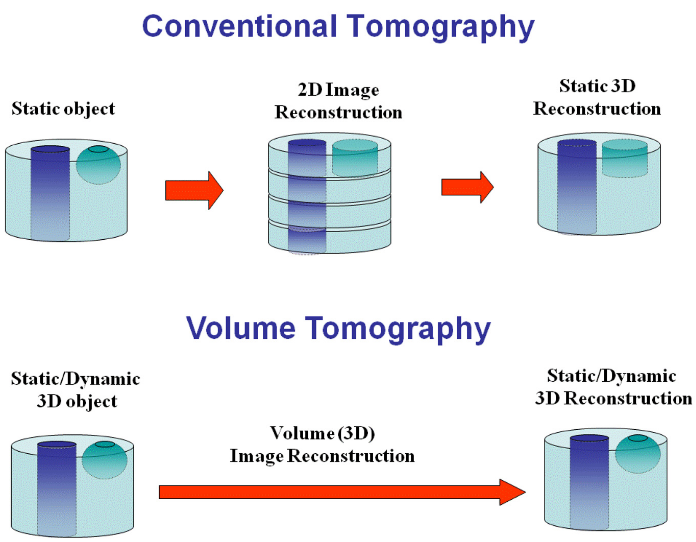
10/01/2008 to 09/30/2011

COST

Total Project Value
$1,158,660

DOE/Non-DOE Share
$899,708/ $258,952

a reconstruction technique (3-D-NN-MOIRT) capable of providing a solution. An illustration of the imaging difference between ECT and ECVT is shown below.



Conventional Tomography required sensors distributed in three dimensions to provide data for reconstructing a 3-D image through solving a complex problem; whereas, Volume Tomography uses small sensors with different shapes and a new reconstruction technique to provide 3-D images.

Goals and Objectives

The goal of the project is to develop a three-dimensional, high-speed capacitance tomography system to image large-scale, cold-flow circulating fluidized beds. The overall objective of the project is to develop and adapt an ECVT system to image multiphase flows common to CFB and evaluate its ability to collect data useful for validating multiphase flow models. The specific objectives of the project include (1) developing high-speed capacitance acquisition hardware with up to 50 imaging frames per second; (2) developing 3-D reconstruction software to view 3-D images of solid concentrations, volume average velocity profiles, average volume granular temperature, and other related properties; (3) designing custom 3-D capacitance sensors for the CFB under investigation to image the flow in the "L-valve" feed, fully developed column, and "elbow" exit regions; (4) conducting thorough analysis of acquired images; and (5) installing the capacitance sensors and deliver a fully operational ECVT system.

Technological Approach

Tech4Imaging will design, fabricate, and demonstrate the ECVT technology in three phases. During Phase I-Development, capacitance measuring technologies, including charge-discharge and impedance-based methods, will be considered for ECVT hardware. Researchers will use electronic computer simulation software(PSpice, and Opera-3-D), to identify optimum sensor designs and perform simulation of the sensitivity matrix. A simulated image reconstruction will validate imaging capability of different sensor designs. During Phase II-Fabrication, the team will identify the optimum acquisition hardware design from those studied in Phase I and will fabricate the sensors and imaging system. During Phase III-Testing, researchers will develop user-friendly image reconstruction software compatible with the acquisition hardware and ECVT sensors. The ECVT system will be demonstrated in an integrated and continuous mode. The ECVT installed in a cold-flow CFB unit will be evaluated for its performance relative to model validation using the modeling software Multiphase Flow with Interphase eXchanges (MFIX).

Accomplishments

The research team has selected the capacitance channel design with proper signal-to-noise ratio and scanning speed. The sensor designs for all three riser sections (Entrance and Exit Elbows, Fully Developed Region)have been completed.

Benefits

Multiphase flows are commonly encountered in industrial operations such as fluid-bed combustors, coal gasifiers, carbon capture processes, and Fischer-Tropsch synthesis. A dedicated 3-D ECVT for imaging fluidized-bed systems will enable more inexpensive exploration of options that may improve the processes involved in producing power using cold-flow circulating fluidized beds. As scientists and engineers better understand the fundamental steps in complex processes, they can optimize the design of the equipment needed. This approach is less costly than performing a long series of experiments under varying conditions to isolate important variables, yields more information, and helps to avoid some scale-up steps traditionally required for full-scale commercialization. Optimization of power production processes will lead to more efficient use of domestic fuel sources with lower emissions in order to support DOE's energy security mission.