Overview of NETL In-House Vision 21 Activities

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Abstract

The Office of Science and Technology at the National Energy Technology Laboratory, conducts research in support of Department of Energy's Fossil Energy Program. The research is funded through a variety of programs with each program focusing on a particular aspect of fossil energy. Since the Vision 21 Concept is based on the Advanced Power System Programs (Integrated Gasification Combined Cycle, Pressurized Fluid Bed, HIPPS, Advanced Turbine Systems, and Fuel Cells) it is not surprising that much of the research supports the Vision 21 Concept. The research is classified and presented according to "enabling technologies" and "supporting technologies" as defined by the Vision 21 Program. Enabling technology include fuel flexible gasification, fuel flexible combustion, hydrogen separation from fuel gas, advanced combustion systems, circulating fluid bed technology, and fuel cells. Supporting technologies include development of advanced materials, computer simulations, computational fluid dynamics modeling, and advanced environmental control. An overview of Vision 21 related research is described, emphasizing recent accomplishments and capabilities.

Introduction

The onsite research office of NETL, the Office of Science and Technology (OST), performs research primarily in support of the Department of Energy's Fossil Energy Program. The research is funded through a variety of programs with each program focusing on a particular aspect of fossil energy. Since the Vision 21 Concept is based on the Advanced Power System Programs (Integrated Gasification Combined Cycle, Pressurized Fluid Bed, HIPPS, Advanced Turbine Systems, and Fuel Cells) it is not surprising that much of OST's research supports the Vision 21 Concept.

Two key Vision 21 Program elements are the development of enabling technologies and supporting technologies. Enabling technologies, like gasification and advanced combustion, form the building blocks of the 21st Century Energy Plants. Supporting technologies are cross-cutting technologies that are necessary for multiple subsystems and components and are important for other applications. OST's research efforts in support of Vision 21 will be classified and described in terms of enabling technologies and supporting technologies.

Enabling technology research conducted by OST

The 21st Century Energy Plant will not consist of a single configuration. It will be a group of plants with different configurations that will be tailored to meet specific market needs. Many plants will produce a combination of power, fuels, chemicals, and process heat. OST is performing research in the following enabling technologies in support of the Vision 21 Program:

Fuel flexible gasification
Fuel flexible combustion
Hydrogen separation from fuel gas
Advanced combustion systems
Circulating fluid bed technology
Fuel cells

Fuel flexible gasification: Coal gasification is an ideal core technology for the Vision 21 energy plant because it provides a fuel stream that can be used for electric power generation, chemical production, or fuel cell operation. In order to maximize fuel flexibility gasification of coal and biomass blends are being tested. At NETL, a 1 ton coal-per-day fluid bed gasifier has been used to characterize coals and coal-biomass blends and assess handling and ash chemistry issues. It has the capability to handle slurry, solid, and blended feedstocks and is being fitted with an additional coarse solids feed system to allow for easy variation of feedstock composition. Test results indicate that blends of sawdust and bituminous coal have fewer operational problems when compared to bituminous coal gasification tests.

Fuel flexible combustion: Some Vision 21 plant have coal combustion as the core technology. Fuel flexibility is sought in these plants too. Pilot-scale evaluations in the Combustion and Environmental Research Facility (CERF) have been conducted to enhance fuel, emissions, and/or efficiency performance in pulverized-coal combustors. Current CERF testing involves evaluating biomass co-firing, including wastes and energy crops. The emphasis is on biomass fuel processing and determining practical limits for particle size and moisture content, as well as evaluating impacts such as carbon burnout, ash deposition, and emissions when firing biomass at 5 to 30 percent on an energy basis.

Hydrogen separation from fuel gas: In support of the fuel cells effort and the gasification technology effort at NETL, OST is developing a facility to process 2000 scfh of fuel gas. The facility contains a syngas generator that produces a synthesis gas that can be tailored to the gas composition of interest. The facility will be used for coal-gas cleanup, natural gas and liquid fuel cleanup/reforming and hydrogen separation. High pressure membrane testing and membrane characterization is studied in conjunction with Argonne National Laboratory.

Advanced combustion systems: Combustion dynamics have been recognized as an industry-wide problem for gas turbine developers. OST is investigating novel approaches to enhance the stability of premix combustion and to determine how low-cost rig tests can be reliably extrapolated to full-engine development. OST is supporting the development of “zero-emission” steam power systems. In this system, water is used as a diluent instead of nitrogen and pure oxygen is used as an oxidizer. The goal is to eliminate nitrogen from the unit so that nitrous oxides are not formed and to have 0% oxygen in the product gas .

Circulating fluid bed technology: The power generation plants of the 21st Century may be either gasification-based plants or combustion based plants but most assuredly will need detailed understanding of gas-solid flow behavior. NETL is undertaking cold gas-solid flow research in its circulating fluid-bed (CFB) system. The CFB is a user facility for private industry to test specific component design and configurations. It has been used to test J-vales, L-valves, and N-valves. It consists of a riser, a two-stage cyclone, a standpipe, a make-up feed hopper and a 2-ft diameter fluidized bed. In addition to testing hardware it has been used to develop a complete data set mapping the hydrodynamic performance characteristics of circulating fluid bed operating regimes using a cork bed material.

Fuel cells: OST is in the process of designing and building facilities and capabilities to support high-temperature fuel cell testing. A prototype testing and evaluation facility is being developed to test a 5kW Solid Oxide Fuel Cell. In addition a cell and stack facility is being used to develop and validate models.

Supporting technologies research being conducted by OST

Advanced materials: To achieve the Vision 21 efficiency objectives, improvements in fabrication materials of energy plants is needed. High temperature ceramic materials and alloy materials are being developed for heat transfer applications. In conjunction with Oak Ridge National Laboratory, University of North Dakota Energy and Environmental Research Center, and NCC Engineering, NETL is conducting pilot-scale combustion tests of metals, claddings, ceramics and coatings. Samples are inserted in various locations where temperatures range from 1700oF to 2600oF with exposures exceeding 1000 hours. These tests allow developers o realistically screen advanced materials, and study corrosion and other gas/ash material interactions that will impact slag screens, heat exchangers, or filter for fossil energy applications.

Computer simulations and CFD modeling: OST has established a Computational Energy Science Focus Area with goals 1) to develop science-based computational tools and apply them to simulate clean, highly efficient energy plants of the future and 2) to develop virtual demonstration capabilities to probe dynamic responses of energy plants and interactions of major components of energy plants. This work is being conducted at 1) meso-scale to develop science-based constitutive laws, 2) device scale to conduct first principle studies of energy conversion devices, and 3) system scale to study coupled systems and to develop dynamic control systems. NETL has been actively developing a strong relationship with the Pittsburgh Supercomputer to provide the platform to conduct this research. The computational group at NETL has developed a computational fluid dynamics code, MFIX, that is ideally suited for fluid-bed applications and works cooperatively with Fluent to enhance their CFD codes for fossil fuel applications.

Desulfurization sorbents: Although sorbent development is an Integrated Gasification Combined Cycle activity that is not rolled into Vision 21, the zero emission target of Vision 21 far exceeds the emission targets of IGCC. NETL is developing the next generation sorbents, regenerable

desulfurization sorbents that are capable of removing sulfur to ppb levels for potential use in fuel cell and chemical production applications, a goal of the Vision 21 Concept. NETL's latest formulation has successfully completed a 20-cycle test conducted at RTI. Originally the sorbent needed to be regenerated at a relatively high temperature (650 ^{0}C) but has been modified to achieve regeneration at 538 ^{0}C while maintaining the ppb level sulfur removal efficiency. The decrease in regeneration temperature results in a more efficient gas purification process.

Selective Catalytic Oxidation of Hydrogen Sulfide: In addition to the sorbent development described above, additional gas purification research is underway. A patent application has been filed for the NETL developed Selective Catalytic Oxidation of Hydrogen Sulfide (SCOHS) Process, a process in which the hydrogen sulfide component in a coal-derived fuel gas is directly converted to elemental sulfur. The envelope of operation for SCOHS has been determined to be between the fuel gas dew point and a maximum temperature of 350°F. This temperature range allows us to take advantage of the higher activation energy, and correspondingly the faster kinetics, necessary for the selective oxidation of hydrogen sulfide over hydrogen and carbon monoxide coal synthesis gas components. In this temperature range hydrogen sulfide was reliably and consistently removed to less than 10 ppmv (the lower end of detection accuracy). A systems analysis study was conducted by Parsons Engineering which showed significant advantages of the SCOHS process over other desulfurization options.

Particulate removal: Reliable high temperature removal of particulates from gas stream has been a continuing research topic. Ceramic filters are capable of high temperature operation but have not shown the reliability needed for long term power plant operation. Early Vision 21 plants may be designed to remove particulates at moderate temperatures so that metallic filters can be used. These filters have been shown to be more reliable than ceramic filters. NETL recently completed a Cooperative Research and Development Agreement (CRADA)that involved testing of Technetics' sintered FeCrAlY Feltmetal candle filter - a metal filter with expected cyclic endurance life and low pressure drop characteristics at an affordable price. The test results of this CRADA are the best among all six filter (ceramic and metallic) CRADAs that have been performed at NETL. As part of our collaboration with Southern Company Services, the operator of the Power Systems Development Facility (PSDF) in Wilsonville, Alabama, a copy of the CRADA Report and a recommendation of field trials at the PSDF were disseminated for review and consideration.

Hot/warm gas cleanup: Recent efforts to conduct hot/warm gas cleanup at commercial scale has not been entirely successful. NETL has been constructing a pre-demonstration facility for testing desulfurization technologies that will provide data and technical support so that future demonstration projects will be more successful. Significant progress has been made in shakedown of the Gas Process Development Unit (GPDU) and the shakedown of the Syngas Generator, which will provide sulfur-laden fuel gas to the GPDU. Using sorbents and transport or fluid-bed contacting, the GPDU will be used to demonstrate the process feasibility of removing sulfur from coal gasification or other fuel gas streams at temperatures above dew point of the gas. This technology, also known as hot or warm gas desulfurization, is expected to remove sulfur to concentrations lower than conventional systems at comparable cost. The GPDU Project was externally reviewed in April, 2001 by industry

representatives, who recommended pursuing shakedown and test operations to demonstrate hot-gas desulfurization technology at the design operating conditions of the unit. Recent major GPDU accomplishments include: 1) cold circulation/recirculation of EXSO3 sorbent (same as used in the Pinon Pine clean coal plant), 2) heat up without solids to nominally 50% of design operating temperature using hot air from both fired preheaters in the system, 3) refractory dry out, 4) confirmation of reactor refractory integrity and circulation piping thermal design, and 5) demonstration of operation with steam. Major Syngas Generator accomplishments include: 1) successful firing of the first stage natural gas-air burner, 2) refractory dry out of the combustion unit, and 3) demonstration of startup operations at up to 2000°F.

Summary

The expectations of the on-site research work are the same as the expectations of the Vision 21 Program. By the year 2015, technology basis for ultraclean and efficient low-cost energy plants will be developed. Simulation tools will be in place that will lower the cost of developing new energy and environmental technologies. Spinoff technologies that include low-cost oxygen and hydrogen separation technology, improved low-cost manufacturing techniques for high-tech components, and better catalysts for producing fuels from low-valued raw materials will be available.