Otter Tail Power Company
Demonstration Project

Benefits Presentation

Power Plant
Improvement Initiative

Full-Scale Retrofit of Advanced Hybrid™ Technology Fabric Filter and Perforated Electrostatic Precipitator

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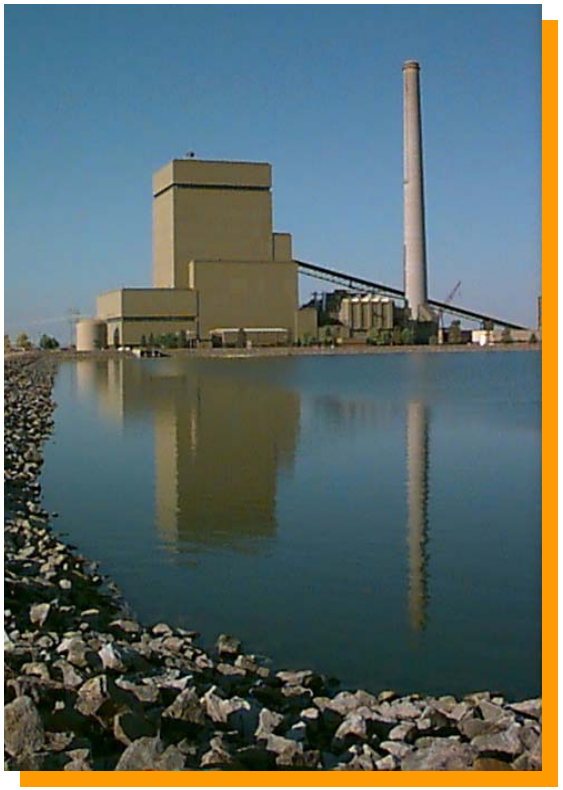
Outline

- **Executive Summary**
- **Project Information**
  - Plant, fuel, location, cost, and schedule
  - Team members
  - Advanced Hybrid™ technology process
  - Advanced Hybrid™ filter schematic



450 MW Big Stone Power Plant

Outline (continued)

- **Estimated Benefits**
  - Approach
  - Market penetration assumptions
  - Technology
  - Pollutant reductions from commercialization
  - Emissions removed
  - Regional
  - National
- **Conclusions**

Executive Summary

- **Otter Tail Power Company designed, constructed and operated an Advanced Hybrid Particulate Collector (Advanced Hybrid™) at the existing Big Stone Power Plant, near Big Stone, SD**
- **Advanced Hybrid™, tested on a 450 MWe cyclone boiler, had potential to raise fine particulate matter ($PM_{2.5}$) capture for coal-fired power plants up to 99.99%**
- **The first six months of operation (November 2002 – April 2003) showed better than 99.99% particulate removal; however, Advanced Hybrid™ was not able to consistently meet project goals due to unresolved issues**
  - Higher than anticipated pressure drop in the membrane filter bags
  - Membrane filter bag failures
  - Poor electrostatic precipitator (ESP) performance

Project Information
Plant, Fuel, Location, Cost, and Schedule

- **A 450 MWe demonstration of Advanced Hybrid™ technology installed on a cyclone boiler firing coal from Wyoming's Powder River Basin**
- **Location: Otter Tail Power's Big Stone Power Plant, Big Stone City, SD**
- **Project cost: $21,359,336; (DOE share: $6.5 million)**
- **Schedule:**
  - 2002 Project Start
  - 2002 Construction
  - 2002 to 2005 Operation
  - 2006 Completion

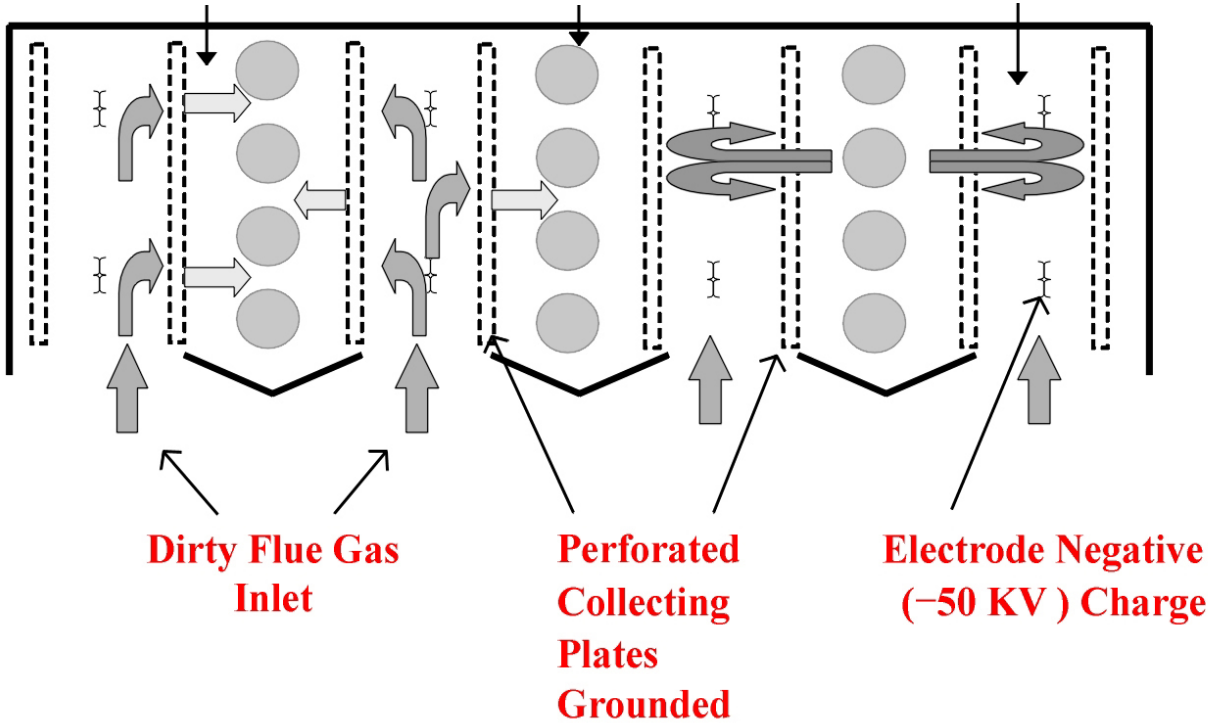
Project Information (continued)
Team Members

- **Otter Tail Power Company**
- **Montana-Dakota Utilities (Bismark, ND) and NorthWestern Public Service (Sioux Falls, SD)**
  - Big Stone co-owners
- **W.L. Gore & Associates, Inc. (Newark, DE)**
  - Advanced Hybrid™ licensee, membrane filter bag supplier
- **University of North Dakota Energy and Environmental Research Center (Grand Forks, ND)**
  - Advanced Hybrid™ concept developer, patent holder, licenser
- **Fuel: Power River Basin (PRB) sub-bituminous coal**

Project Information (continued)
Advanced Hybrid™ Filter Schematic

Flue gas first flows by electrodes to electrically charge the particulate, then through perforated plates where particulate are collected, and then to membrane filter bags to capture ultra-fine particulate

During bag cleaning, dust cake is projected through plates and captured in ESP zone



Project Information (continued)
Advanced Hybrid™ Technology Process

- **A description of project process is given below, recognizing that additional development by private sector would be required to achieve commercialization**
  - A potentially high efficiency particulate control device with membrane filter bags interspersed with perforated electrostatic precipitator (ESP) plates and electrodes in same housing
    - Metal plates run the length of collector and contain numerous circular openings
    - Behind plates are membrane filter bags
  - When flue gas enters device
    - An estimated 90% of the fly ash particles become electrostatically charged and adhere to ESP like plates
    - Particles eluding plates, flow through openings and are trapped by the membrane filter bags

Estimated Benefits
Approach

- **Assuming further development of Advanced Hybrid™ is pursued by private sector and technology reaches maturity, benefits estimation would proceed as follows**
  - Forecast market penetration
  - Quantify differences between performance of conventional technology and the anticipated performance of the Advanced Hybrid Particulate Collector being demonstrated
    - Pollutant emissions, tons per year
    - Capital cost, constant dollars

Estimated Benefits (continued)
Market Penetration Assumptions[1]

- **Individual boilers most likely to install Advanced Hybrid™ were selected[2] based on specific attributes that made them most likely to benefit from that technology**
  - Equipped with pollution control equipment that includes a cold-side ESP but not an SO_2 scrubber
  - Capacity factor of at least 0.80
  - ESP in-service date: 1982 or before
  - Boilers that came on line after 1962
- **25,614 MWe of existing power plants selected as basis of benefits estimation**

[1] Assuming further development by the private sector to reach commercialization is successful

[2] NETL Coal Power Data Base

Estimated Benefits (continued)

Potential Pollutant Reductions from Commercialization[1]

Pollutant	AHPC Emission Reductions, tons/year	All Boiler Emissions, tons/year
Total Particulate Matter	52,580[1]	522,400
PM_{10}	35,670[1]	360,900
$PM_{2.5}$	16,230[1]	167,100
SO_2 [2]	202,700[1]	10,770,000

[1] Assuming further development by the private sector to reach commercialization is successful

[2] Basis: AHPC technology would facilitate 4.7 GWe of generating capacity to switch to low sulfur coal.

Note: PM10 and PM2.5 emissions were estimated using generalized emissions factors.

Estimated Benefits (continued)
Emissions Removed[1]

Status	Total Particulate Emissions, tons/year
Before Retrofit	360
After Retrofit[1]	130
Emissions Avoided[1]	230

An early project emissions test revealed a stack dust loading of 0.00003 pounds/million Btu, which is equivalent to a removal efficiency of 99.998%

[1] At a nominal 450 MWe cyclone-fired boiler fueled primarily by PRB coal and assuming further development by the private sector to reach commercialization is successful

Estimated Benefits (continued)
Regional

- **Commercialized[1] version of Advanced Hybrid™ technology could provide greater fuel flexibility to plant operations (can use PRB coal)**
  - Boiler operations would no longer be curtailed due to opacity limits being exceeded
  - Region would benefit due to lower particulate emissions

[1] Assuming further development by the private sector to reach commercialization is successful

Estimated Benefits (continued)
National

- Additional development by private sector is required to ready this technology for commercialization
- Advanced Hybrid™ technology, once commercialized, could save capital costs when compared to the installation of conventional fabric filter systems to achieve the same low particulate emissions

Conclusions

- **Assuming further development by the private sector to reach commercialization is successful, Advanced Hybrid™ technology could potentially enable the following benefits:**
  - PRB coal burned in units where existing ESP's cannot effectively capture high-resistivity dust;
  - Additional fuel switching options
  - Avoiding plant peak load deratings

Full Scale Advanced Hybrid™ Retrofit At Big Stone

Visit the NETL web site for information on all Power Plant Improvement Initiatives and Clean Coal Power Initiative projects

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