Energy & Environmental Research Center University of North Dakota
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Project Title: Integrated Gas Turbine–Gasifier Pilot-Scale Power Plant

Contract Number: RD3-71 Milestone Number: 9 Report Date: Aug 1, 2011

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Congressional District (Corporate office): Not Applicable

Congressional District (Project location): Not Applicable

MILESTONE REPORT

Executive Summary: During this milestone period, the Energy & Environmental Research Center (EERC) completed Milestone 9; complete power system construction. The modified microturbine has been installed in the system with the associated piping, valves, and instrumentation, completing the construction of the power system. Work is ongoing on Milestones 10-12. Project funding was provided by customers of Xcel Energy through a grant from the Renewable Development Fund.

Technical Progress: Figure 1 shows a simplified system design for a conventional gas turbine based power system. Compressed air is preheated by a recuperator and then injected into a combustor. The hot, pressurized gas exiting the combustor turns the expansion turbine which, in turn, operates the compressor and electric generator. Syngas from a gasifier must be cleaned of particulates and acid gases, and compressed to high pressure to inject into the combustor. The compressor cannot handle hot input gases, requiring cooling of the syngas before compression. This, in turn, requires extensive syngas scrubbing systems between the gasifier and compressor. The capital and operating costs of the syngas scrubbing system in this type of design may exceed that of the gasifier and gas turbine, making this system uneconomical for distributed power production.

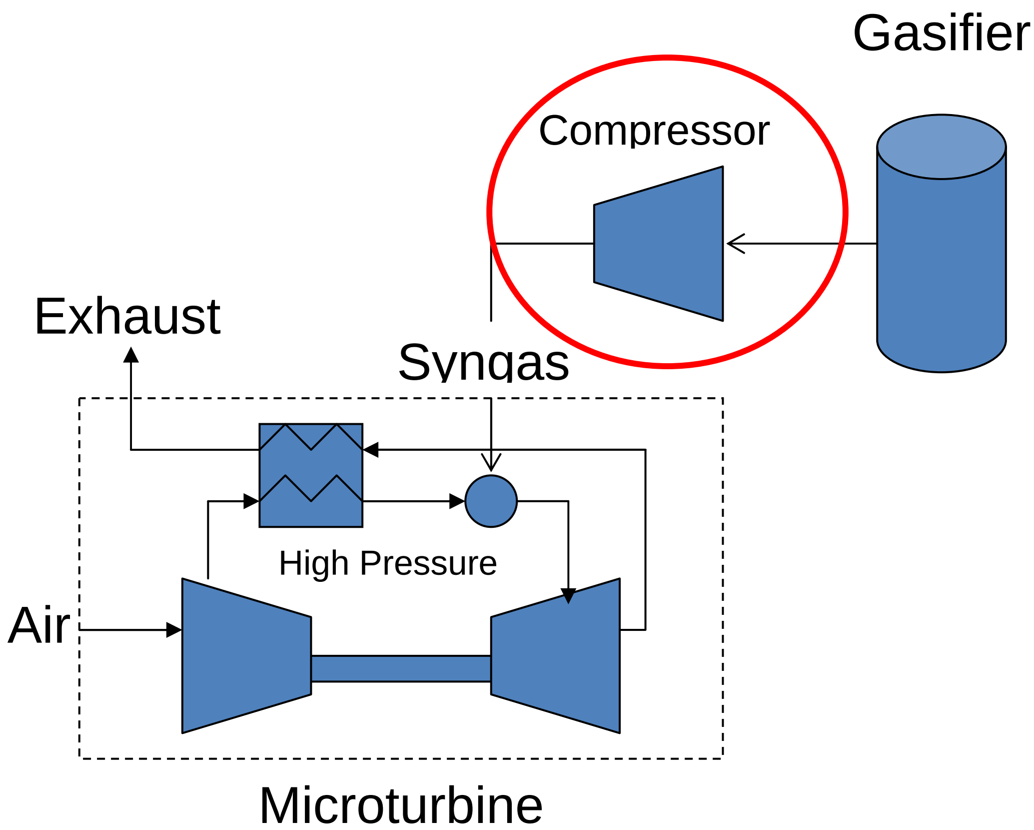

Figure 1. Directly heated gas turbine system for biomass power production

To overcome these issues, the system was designed to employ an indirectly heated gas turbine, as presented in Figure 2. Hot syngas is fed to an atmospheric combustor which then heats high temperature air through a high temperature heat exchanger. The high temperature heat exchanger is designed to reduce gas temperatures to an acceptable level for the stock recuperator. Since the syngas never contacts the high speed turbine, particulate cleanup requirements are greatly reduced. The compressor is eliminated, and the need to cool the syngas below the condensation temperature of tars is also eliminated. This eliminates tar fouling in the pipes and greatly reduces the particulate cleanup requirements.

The EERC has modified an off-the-shelf Capstone C30 microturbine to move the combustor out of the high pressure zone and into the low pressure zone. A new combustor and heat exchanger was installed in the microturbine to work with the stock recuperator.

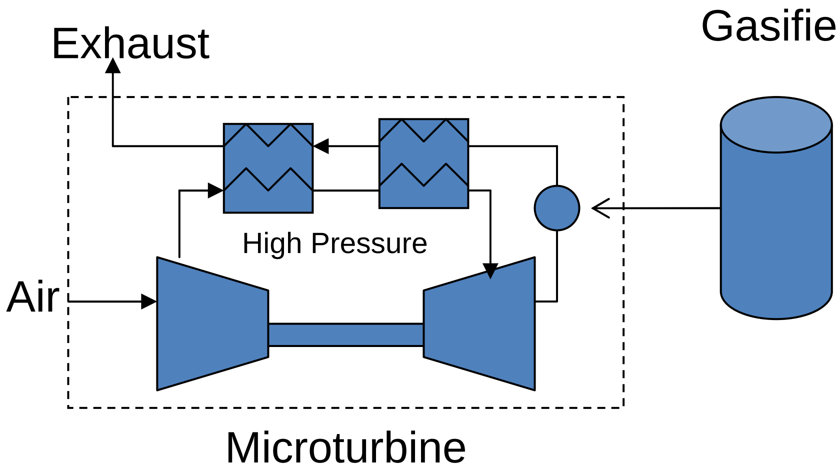

Figure 2. Indirectly heated gas turbine system for biomass power production

The microturbine modifications were completed in November and testing commenced in December. Figure 3 shows an image of the modified microturbine. Both the high temperature heat exchanger and combustor are integrated into a single unit and installed directly to the recuperator to minimize pressure losses. Initial testing produced several start-up faults from the stock C30 software. In addition each time the new igniters were turned on for the combustor, excessive electromagnetic interference from the cables feeding the igniters interfered with communication from the controlling laptop to the C30 control hardware. During initial testing, one of the circuit boards in the C30 stopped working. The igniter cables were shielded and the circuit board replaced. Concurrent testing was able to overcome the initial start-up faults. Testing is ongoing to overcome additional faults in the stock software.

Figure 3 Image of indirectly heated microturbine

This quarter the EERC worked on Milestones 9. The following additional modifications were made to the turbine to overcome the limitations encountered during the first round of testing:

1. Independent burner nozzles were added to provide independent air and fuel premixing within the combustor.
2. The size of the heat exchanger was increased by an order of magnitude to provide increased heat transfer. This was made possible by observations of the air flow patterns at the output of the expander.
3. The input to the high pressure vessel of the turbine was thermally isolated from the output. This will increase peak temperature at the expander inlet and overall heat transfer of the heat exchanger.
4. Installation of the microturbine to the gasification system with associated valves, piping and instrumentation.

During subsequent testing on the microturbine the control computer lost communication with the turbine. The troubleshooting and replacement of the communications board on the microturbine delayed installation of the microturbine to the gasifier by approximately 1 month.

Figure 4 shows the line diagram of the completed power system. Figure 5 shows an image of the gas turbine operating on syngas directly from the biomass gasifier.

The gasifier will be started on charcoal and brought up to operating temperature on biomass. The syngas produced during this time will be flared to atmosphere. Once the gasifier reaches steady state, the microturbine will be started on natural gas and brought up to a steady state operating temperature of 900^{o}C in the combustor. At this point, the syngas valve will be opened. The flare valve will be incrementally choked, while simultaneously closing the natural gas input. Throughout this stage the microturbine combustion temperature will be maintained at 900^{o}C. When the natural gas lines are fully closed the system will be operated over an extended time to determine both the gross and net power outputs of the system at steady state operating conditions.

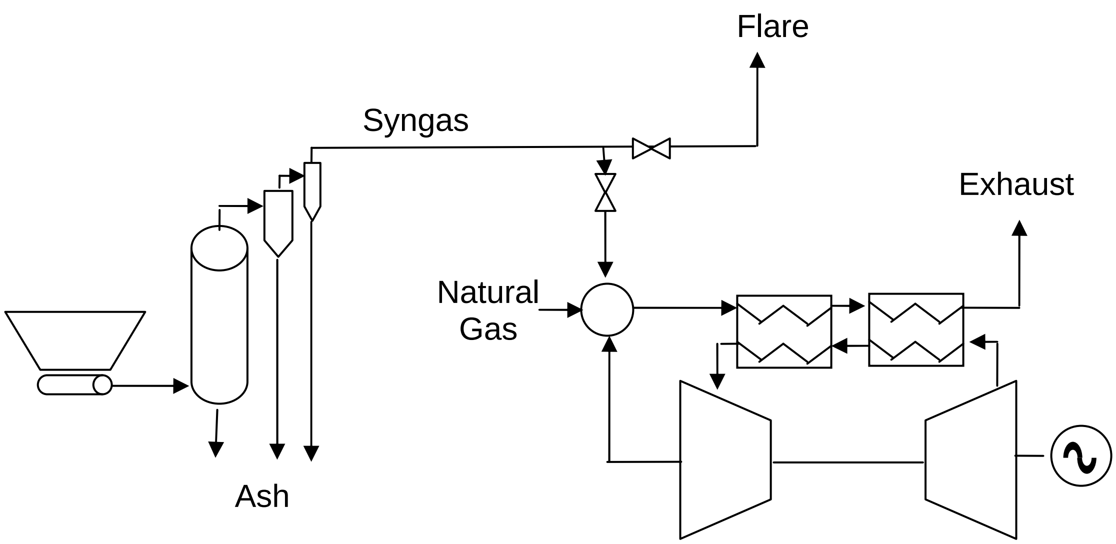

Figure 4. Line diagram of microturbine – gasifier test system

Figure 5 Modified Capstone microturbine operating completely on syngas directly from the biomass gasifier

Additional Milestones/Project Status: Work has commenced on Milestones 10 – 12.

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