Optimizing the utilization of biomass resources for power generation in Brazilian sugarcane industry through application of co-fired combined cycles

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Sugarcane bagasse and sugarcane trash are residues from sugar and alcohol production, an economic activity that is well established in Brazil. Bagasse is a residue from the industrial process, being widely used in CHP plants to fulfill thermal and power requirements of sugarcane mills. As the market for surplus bagasse is small and unstable, mills usually consume all this biomass in CHP plants of very low biomass-to-electricity efficiency. Tops and leaves of the sugarcane plant – the so-called sugarcane trash – are currently just burned in the field before manual harvesting. As this practice is going to be reduced for environmental reasons, it is predicted that the availability of sugarcane residues in Brazil will steadily increase in the coming years. Sugarcane trash should be recovered from the fields through mechanic harvesting, technology that has started to be applied in Brazil during the last few years. The full potential of electricity production from sugarcane residues is estimated as about 10-12 GW, a very impressive figure specially when compared to the current installed capacity of CHP schemes in this industrial branch (less than 1 GW) [1].

Conventional steam power cycles have 15-25 per cent biomass to electricity efficiency. CHP plants in sugarcane mills have even lower efficiencies (general sense, less than 10 per cent). It is supposed that with not yet commercially available BIG-CC cycles the efficiency of electricity production could reach 35-45 per cent. As the main primer mover of such power cycles, performance penalties associated with gas turbine adaptation to gasified biomass are meaningful. Biomass syngas has just about 10 per cent of the energy content of natural gas, resulting in much larger mass flow through gas turbines. As consequence, technical problems can be observed on such machines, such as compressor surge, increased thermal and mechanical loads on compressor airfoils, the need of an adapted combustion/injection system and problems with flame stability.

In a project that has been developed in Brazil and in The Netherlands, co-firing (natural gas + biomass synthetic gas) is suggested as a way to raise the heating content of the fuel gas in order to minimize these technical problems. Mixing natural gas to syngas is proposed mainly as a short-term approach to cope with penalties on both efficiency and power resulting from de-rating (reduction of maximum gas turbine temperature). In BIG-CC systems, de-rating might be necessary for some gas turbines that cannot cope with increasing pressure ratio when only syngas is burned. It is estimated that the natural gas share on fuel mix that could offset de-rating varies between 30-50%, depending on GT characteristics. Furthermore, increasing the heating content of the fuel gas is desirable in order to avoid significant burner modifications, to increase combustion stability and to reduce the risk of back stream flame propagation. Simultaneous use of natural gas and low heating content gases has been demonstrated for more than 60,000 hours in a steel mill located in Taranto, Italy [2].

Besides the possibility of overcoming technical constraints for the very first BIG-CC units, the enlargement of the fuel heating value due to the natural gas contribution boosters the plant efficiency and, consequently, contributes to the reduction of electricity cost. In this sense, also from an economic point of view co-firing could be instrumental for the market development of the BIG-CC technology in its early stage. In addition, the co-firing proposal is backed by increasing availability of natural gas in Brazil, especially with the imports of large amounts from Bolivia. Bulk amounts should be used in thermal power plants during the early years of a take or pay supply contract, as the natural gas market is not well developed in the country. As long as premium market (e.g., in the residential and commercial sector) getting developed, natural gas could be gradually move from power generation to more adequate uses. A time frame of about 10-15 years is predicted both for full development of BIG-CC technology and for the development of natural gas market.

Co-fired combined cycles could be installed in the mill site, operating as a cogeneration unit during the harvest season, or even in thermal power plants, outside the mills. Theoretically, the best site option depends on the trade-off between biomass transportation cost and a set of other constraints, such as availability of natural gas, required investments for access to the grid and for electricity transportation, predicted water consumption and water availability, etc. Preliminary results of an economic assessment show that electricity costs are less sensitivity to biomass transportation costs, but for plants larger than 150 MW both biomass transportation costs and logistics should be carefully considered. The Bolivia-Brazil pipeline is very close to the region where most of the sugarcane production is based in the state of São Paulo (in which about 70 per cent of sugarcane is produced in Brazil), that means that best places for co-fired power plants can be defined very close or even inside the mill sites.

The issue of optimum plant size is of the high interest for two reasons. First, because of the obvious importance of the cost of electricity produced from the point of view of system's feasibility. Second, and no less important, from the point of view of the cost of electricity produced from biomass. Preliminary results show that in a co-fired plant the cost of the same amount of electricity exclusively produced from biomass (the base for comparison is a 100 MW biomass-based capacity) is 15 per cent less than the calculated cost of a pure BIG-CC plant. In fact, the main advantage of a co-firing scheme based on biomass gasification and natural gas is on the gains of scale-effects and higher efficiency, without scaling up the gasification equipment. In this sense, co-fired combined cycles could be a good short term alternative to produce green electricity from biomass.

Considering the huge potential of electricity production from sugarcane residues, it is important to notice that sugarcane activity is seasonal and, as consequence, bagasse and trash are available just during 7-8 months of the year. To extend power production all over the year it would be necessary to storage bagasse and trash or to use a complementary fuel. Sugarcane harvesting occurs in Brazil during the dry season, when hydroelectric power plants can not operate under their full power capacity. Currently hydroelectricity covers more than 90 per cent of Brazilian electricity needs, but future capacity expansion should be based on natural gas. One important aspect of the "co-firing" proposal is the potential synergy among hydro, natural gas and biomass from the point of view of electricity production.

Co-fired combined cycle units can operate with other sources of biomass. In fact, the use of wood from dedicate forests has better short-term perspectives than sugarcane residues due to the stage of development of wood gasification. General sense, conditions that should be observed regarding biomass supply are the low cost of the biomass resource and a relatively small distance between biomass plantation and natural gas pipeline.

References

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