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Opinion Article

Carbon Dioxide Recovery Skid

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Abstract

"In the face of tightening climate regulations, the adoption of carbon dioxide recovery systems is inevitable. Modular process skid units have been widely adopted across the industry. The gas-steam power plant skid unit with the carbon dioxide recovery system was described. The proposed skid module consists of the compact cycle with the oxy-combustion and the carbon dioxide capture skid unit producing pure compressed CO2. The compactness of the suggested skid can be achieved due to a novel small size designs of the wet combustion chamber and the spray-ejector condenser."

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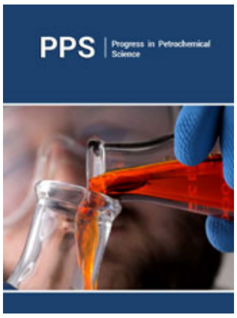

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Opinion

Nowadays more and more plants walk away from building various process systems on-site and rely on suppliers for ready to connect modules. Suppliers who are usually the manufacturers (or a proxy between a manufacturer and a contractor) deliver these process systems that are built under off-site conditions. As a result of that, modular constructions have been adopted for ease of handling in commercial use. Such a mobile construction of a process system is called "skid" in English or "anlage" in German. Skids are usually built within a frame. Depending on the dimension of a skid and logistical planning, it can fit, for example, on the back of a truck or in the shipping container [1,2].

Most factories emit a certain volume of carbon dioxide (CO_2). For example power plants, oil rigs, refineries, waste incinerators, sewage treatment plants, etc. Recent climate restrictions imposed a reduction of CO_2 emissions to the environment. As result, a feasible way to capture the CO_2 was searched. Depending on the costs and size of a plant, some have decided to build CO_2 capture systems onsite, while others (usually smaller) have made decision to pay emission fees. CO_2 capture systems built onsite are usually large and may cause additional operational problems. Currently, another rare possibility is to add a compact CO_2 capture skid, that solution can benefit both medium and smaller factories. Demand for building reliable systems in the market caused skid manufacturers to build dedicated CO_2 recovery systems. Before delivery to a plant, a commercial CO_2 skid should be factory acceptance tested (FAT) and certified for its operational use on a manufacturer site, which is an advantage in comparison to these built on plant site without a guarantee [2].

An example of a compact module including CO_2 capture process is presented in articles [1,3,4]. The proposed power plant module is composed of a gas-steam cycle (with CO_2 separation) coupled to a CO_2 capture system as shown in Figure 1. The compactness of the proposed gas-steam power plant skid is achieved due to a novel small size designs of the water combustion chamber (WCC) and the spray-ejector condenser (SEC), both based on enhancements of the energy conversion. Conventionally, the size of a combustion chamber and a condenser would be about 30-fold and 32-fold greater than the WCC and the SEC, respectively.

Starting with the WCC in the gas-steam cycle part, the oxy-combustion process takes place, where supplied methane is burnt in the presence of clean oxygen supplied from the ASU through the compressor C_{O2}. The ASU separates the high-purity oxygen from atmospheric air basing on the cryogenic method. The waste gas from the ASU is then directed to the GT_{N2} expander which is connected to the main shaft. Due to a high temperature of the oxy-combustion in the WCC, the chamber walls are refrigerated by the water injection. Injected water acting as an inert medium, evaporates at the nano level to the combustion chamber.

The working fluid exiting the WCC, which consists of 10-20% CO_2 vapor and 80-90% steam is directed to expand in the vapor turbine GT and the vacuum vapor turbine GT^{bap}. In the literature there is also the name of the gas-steam turbine in relation to the vapor turbine (GT + GT^{bap}) [1,3,4]. Both turbines are connected to the main shaft with the generator G, the oxygen compressor C_{O2} and the expander GT_{N2}. The exhaust vapor leaving the GT^{bap} is directed to the SEC after cooling in the regenerative heat exchanger HE. The vacuum in the SEC is generated in the result of properly sprayed nano-droplets of water through the nozzle longitudinally to the main jet, while the working fluid is sucked perpendicularly to the main jet and then immediately mixed in the path of sprayed water. In the main jet, the steam fraction is partially condensed and CO_2 compressed simultaneously. The mixture of water steam, liquid water, and compressed CO_2 leaves the SEC and raises its pressure to 1bar entering the condensate-cooler exchanger with the separator CHE+S. In the CHE+S liquid water is cooled, while the remaining mixture of steam water and CO_2 is separated in the result of the main jet action in the SEC. Some of cooled water exiting CHE+S is pumped back to the SEC spraying nozzle. The rest of water is pumped back to the WCC after being preheated in the HE, while an excess of water is being removed (which is produced during combustion) [1,3,4].

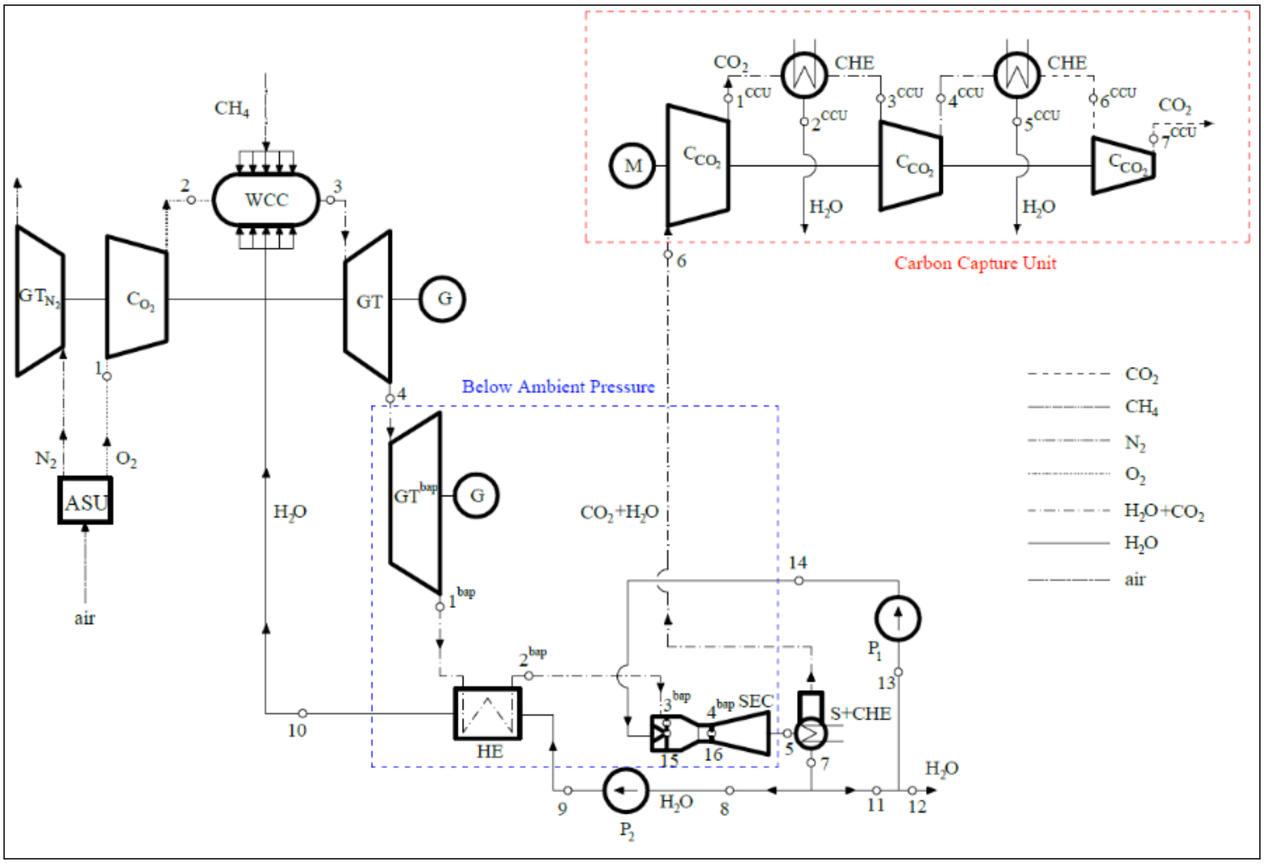

Figure 1: The compact cycle with oxy-combustion and CO_2 capture, where WCC - wet combustion chamber, $GT+GT^{bap}$ - vapor turbine divided into two parts, SEC - spray ejector condenser, ASU - air separation unit, C_{O2} - compressor, HE - regenerative heat exchanger, CHE+S - condensate-cooler heat exchanger and separator, CHE - cooling heat exchanger, M - motor, G - generator, P_1 - supply water pump, P_2 - water pump for cooling combustion chamber, GT_{N2} - expander N_2, C_{CO2} - CO_2 compressor.

In the CO_2 recovery part, the mixture of compressed CO_2 and steam from the CHE+S separator from the gas-steam cycle skid is directed to series of CO_2 compressors C_{CO2} powered by a motor, between compressors water is condensed from the steam in the cooling heat exchangers CHE. As the result, clean compressed CO_2 is produced from the outlet of the CO_2 recovery skid.

In conclusion, the feasible way to capture CO_2 was presented within the compact build of power plant skid. Wide commercial application of such skids including CO_2 capture is the matter of certain factors, like the cost of a CO_2 capture skid unit, the climate regulations, the CO_2 emission fees, and the size of a plant. While the cost of manufacturing of a compact CO_2 uptake skid will possibly reduce, both the CO_2 fees are likely to be increased and the climate regulations be tightened with time. It can be assumed that the balance of these factors will shift toward the cost-effective application of CO_2 reuptake skid units. Especially smaller factories would benefit from this. From the technical view, the development progress of viable CO_2 capture skids is demanded to be done to maintain this trend.

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