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Advanced concept of coupling solar-aided flue gas treatment and solar-aided power generation in power plants

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ABSTRACT

In this paper, an advanced concept of coupling solar-aided flue gas treatment (SAGT) and solar-aided power generation (SAPG) is proposed to realize the low energy consumption flue gas treatment for fossil fuel power generation systems. An improved flue gas treatment sequence outside boilers is proposed in SAGT, where denitration is configured downstream of flue gas desulfurization (FGD). By using a parabolic trough collector (PTC) solar field, flue gas can be heated up to 550 °C in the collectors. The treatment sequence therefore can be achieved with the assistance of solar field. Finally, the waste heat of flue gas is utilized to preheat the feed water of boilers to enhance the power generation of power plants. A 600 MW coal-fired power plant system is analyzed as a case study. The calculation results show that SAGT and SAPG have relatively good performances both on stability and solar-to-electricity efficiency. This study might provide a new solution to deal with the difficulties of treating flue gas inside boilers such as deactivation and blockage of catalysts. Furthermore, efficient utilization of solar energy realizes both environment protection and energy conservation.

Nomenclature

$\widetilde{G}_{NO}$	The mass of NO (kg/kg coal)
$\widetilde{N}_{TA}$	The amount of substance of theoretical air (mol/kg coal)
$\widetilde{n}_{NOx}$	The amount of substance of NO_x (mol/kg coal)
$\widetilde{n}_{CO_2}$	The amount of substance of CO_2 (mol/kg coal)
$\widetilde{n}_{O_2}$	The amount of substance of O_2 (mol/kg coal)
$\widetilde{n}_{N_2}$	The amount of substance of N_2 (mol/kg coal)
q_f	The low heating value of the raw anthracite (kJ/kg)
θ	Incident angle (°)
β	The conversion rate of nitrogen to NO in fuel (%)
β_{cov}	The conversion rate of decomposing NO (%)
$c_{NO,0}$	The initial concentration of NO (mol/m^3)
c_{NO}	The concentration of NO (mg/Nm^3)
P_{reac}	The pressure of flue gas in reactor (Pa)
T_{reac}	The temperature of flue gas in reactor (K)
r_{NO}	Reaction rate of NO (mol/(m^3·s))
τ	The residence time or reaction time (s)
k_{app}	The apparent rate constant (-)
K_α	The equilibrium constant (-)
$\dot{Q}_{abs}$	The thermal energy absorbed by flue gas (W)
$\varphi_{NO,0}$	The initial volume fraction of NO (%)
I	Direct normal irradiation (W/m^2)
T_{ave}	Average temperature of solar field (K)
$T_{sfield,i}$	Temperature of flue gas in the inlet of solar field (K)
$T_{sfield,o}$	Temperature of flue gas in the outlet of solar field (K)
$\dot{m}_{ms}$	The mass flow rate of the main steam (kg/s)
$\dot{m}_{rh}$	The mass flow rate of reheat steam (kg/s)
$\dot{m}_{coal}$	The consumption rate of coal (kg/s)
$\widetilde{h}_{fg}$	The enthalpy of flue gas (kJ/kg coal)
$\Delta\widetilde{h}_{fg,n}$	The enthalpy drop of flue gas after heat exchanging between flue gas and feed water, n = 1, 2, 3,4, 5, 6 (kJ/kg coal)
$\widetilde{m}_{ms}$	The mass of the main steam produced per kg of coal (kg/kg coal)
q_j	The specific enthalpy drop of extraction steam (kJ/kg)

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