Claims

1. A system (3) for controlling an argon flow rate of a fluid (120) at an outlet of an assembly (1) of at least one distillation column in order to achieve a target dioxygen content (SP), the system comprising:

   - a sensor (9) designed to measure a dioxygen content (PV) in a fluid comprising argon at the outlet of the assembly of at least one distillation column,

   - a regulator (11) designed to determine a required argon flow rate variation (Δ_{regul}) depending on the difference (ε) between the dioxygen content measured by the sensor and the target dioxygen content,

   - a controller (13) designed to generate a control signal relating to a target argon flow rate (Q_{argon}), said target argon flow rate being determined depending on the required argon flow rate variation determined by the regulator and on variations in the dioxygen content measured by the sensor, and

   - a valve (15) controlled by said controller and designed to modify the argon flow rate of the fluid at the outlet of the assembly of at least one distillation column in order to obtain the target argon flow rate;

   - wherein the target argon flow rate determined by the controller being determined additionally depending on a predictive value (Q_{pred}) of the argon flow rate depending on an air flow rate (Q_{air}) at an inlet of the assembly of at least one distillation column and on a yield (ρ) of said assembly; and

     wherein the predictive value of the argon flow rate depends on an air flow rate (Q^*_{air}) which is delayed relative to the air flow rate at the inlet of the assembly (1) of at least one distillation column, said delayed air flow rate being defined as follows:

$$Q^*_{air}(t) = Q_{air}(t) \text{ while } Q_{air}(t) - Q_{air}(t-\delta) < R$$
$$\text{if, at } t = t_0, R \leq Q_{air}(t_0) - Q_{air}(t_0 - \delta), \text{ then:}$$
$$Q^*_{air}(t) = Q_{air}(t_0 - \lambda) \text{for all } t \in [t_0; t_0 + \lambda]$$

where:

- $Q^*_{air}(t)$ is the delayed flow rate at time t,
- $Q_{air}(t)$ is the air flow rate at the inlet of the assembly of at least one distillation column at time t,
- t_0 is any time,
- λ and δ are predetermined periods of time,
- R is a predetermined positive threshold.

2. The system as claimed in claim 1, wherein the assembly of at least one distillation column is supplied with an air fluid (100).

3. The system as claimed in claim 1, wherein the predictive value of the argon flow rate at a given time is determined as follows:

$$Q_{pred}(t) = Q^*_{air}(t) \times \alpha \times \rho$$

where:

- $Q_{pred}(t)$ is the predictive value of the argon flow rate at a given time *t*,
- α is the proportion of argon in the air flow at the inlet of the assembly of at least one distillation column,
- ρ is the yield of the assembly of at least one distillation column.

4. The system as claimed in any of claims 2 to 3, wherein the yield of the assembly of at least one distillation column is determined by applying a predetermined function to a factor characterizing an amount of energy used for operating the assembly of at least one distillation column.

5. The system as claimed in claim 4, wherein the predetermined function is determined by a learning algorithm on the basis of a set of data relating to a plurality of distillation processes implemented according to different values for the amount of energy used.

6. The system as claimed in claim 5, wherein the predetermined function is polynomial.

7. The system as claimed in one of the preceding claims, wherein the target argon flow rate is determined depending on an anticipation parameter (P) relating to the variations in the dioxygen content measured by the sensor, said anticipation parameter taking discrete values within a set of predetermined values.

8. The system as claimed in claim 7, wherein the anticipation parameter relating to the variations in the dioxygen content is defined as follows:

$$P(t) = \begin{cases} P_1 \text{ if } |PV(t) - PV(t-\tau)| \leq S \\ P_2 \text{ if } PV(t) - PV(t-\tau) > S \\ P_3 \text{ if } PV(t) - PV(t-\tau) < -S \end{cases}$$

where:

- P(t) is the value of the anticipation parameter relating to the variations in the dioxygen content measured by the sensor at time t,
- P_1, P_2, P_3 are possible values of the anticipation parameter according to the variations in the dioxygen content measured by the sensor,
- PV(t) is the value of the dioxygen content measured by the sensor at time t,
- τ is a predetermined period of time, and
- S is a predetermined threshold.

9. The system as claimed in claim 8 taken in combination with claim 2, wherein the anticipation parameter relating to the variations in the dioxygen content measured by the sensor is a corrective flow rate, the target argon flow rate being determined as follows:

$$Q_{argon} = Q_{pred} + \Delta_{regul} + P$$

where:

- Q_{argon} is the target argon flow rate,
- Q_{pred} is the predictive value of the argon flow rate,
- Δ_{regul} is a required argon flow rate variation, and
- P is the value of the corrective flow rate.

10. The system as claimed in claim 8 taken in combination with claim 2, wherein the anticipation parameter relating to the variations in the dioxygen content measured by the sensor is a weighting coefficient of the predictive value of the argon flow rate, the target argon flow rate being determined as follows:

$$Q_{argon} = Q_{pred} \times P + \Delta_{regul}$$

where:

- Q_{argon} is the target argon flow rate,
- Q_{pred} is the predictive value of the argon flow rate,
- Δ_{regul} is a required argon flow rate variation, and
- P is the value of the weighting coefficient of the predictive value of the argon flow rate.

11. The system as claimed in one of claims 1 to 10, wherein the argon flow rate predictive value is weighted by a corrective factor (K) relating to disturbances of the assembly of at least one distillation column, said corrective factor being determined depending on

the difference between the dioxygen content measured by the sensor and the target dioxygen content.

12. The system as claimed in claim 11, wherein the corrective factor is defined as follows:

$$K = \begin{cases} K_1 \text{if } PV(t) - SP \geq T_1 \\ K_2 \text{ if } T_2 < PV(t) - SP < T_1 \\ K_3 \text{ if } PV(t) - SP \leq T_2 \end{cases}$$

where:

- K_1, K_2 and K_3 are predetermined possible values of the corrective factor, and
- T_1 and T_2 are predetermined thresholds.

13. The system as claimed in one of the preceding claims, wherein the regulator is a PID ("*proportional-integral-derivative*") controller configured such that the values of the parameters respectively relating to the proportional and integral contributions of the PID controller are multiplied by two when the dioxygen content measured by the sensor is greater than the target dioxygen content.

14. The system as claimed in claim 13, wherein the PID controller is a PI controller.

15. The system as claimed in one of the preceding claims, wherein the target dioxygen content of the argon fluid at the outlet of the assembly of at least one distillation column is less than 2 ppm.

16. The system as claimed in claim 15, wherein the target dioxygen content of the argon fluid at the outlet of the assembly of at least one distillation column is between 0.9 ppm and 2 ppm.

17. The system as claimed in claim 15 or 16, wherein the target dioxygen content of the argon fluid at the outlet of the assembly of at least one distillation column is equal to 0.9 ppm.

18. A process for controlling an argon flow rate of a fluid (120) at an outlet of an assembly (1) of at least one distillation column in order to achieve a target dioxygen content (SP), the process comprising:

- measuring a dioxygen content (PV) in a fluid comprising argon at the outlet of the assembly of at least one distillation column,
- determining a required argon flow rate variation (Δ_{argon}) depending on the difference (ε) between the measured dioxygen content and the target dioxygen content,
- determining, depending on the required argon flow rate variation and on variations in the measured dioxygen content, a target argon flow rate (Q_{argon}), and
- modifying the argon flow rate of the fluid at the outlet of the assembly of at least one distillation column in order to obtain the target argon flow rate;
- wherein the target argon flow rate is determined additionally depending on a predictive value (Q_{pred}) of the argon flow rate depending on an air flow rate (Q_{air}) at an inlet of the assembly of at least one distillation column and on a yield (ρ) of said assembly; and

  wherein the predictive value of the argon flow rate depends on an air flow rate (Q^*_{air}) which is delayed relative to the air flow rate at the inlet of the assembly (1) of at least one distillation column, said delayed air flow rate being defined as follows:

$$Q^*_{air}(t) = Q_{air}(t) \text{ while } Q_{air}(t) - Q_{air}(t-\delta) < R$$
$$\text{if, at } t = t_0, R \leq Q_{air}(t_0) - Q_{air}(t_0 - \delta), \text{then:}$$
$$Q^*_{air}(t) = Q_{air}(t_0 - \lambda) \text{for all } t \in [t_0; t_0 + \lambda]$$

  where:

  - $Q^*_{air}(t)$ is the delayed flow rate at time t,

- $Q_{air}(t)$ is the air flow rate at the inlet of the assembly of at least one distillation column at time t,
- t_0 is any time,
- λ and δ are predetermined periods of time,
- R is a predetermined positive threshold.

19. A computer program comprising instructions for implementing the process as claimed in claim 18 when said instructions are executed by at least one processor (19).