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(54) **GAS TURBINE PLANT FOR THE PRODUCTION OF ELECTRICAL ENERGY**

(57) A gas turbine plant for the production of electrical energy is provided with at least one combustor (4) comprising a combustion chamber (20) in which, in use, combustion occurs, and with at least one burner assembly (22) facing the combustion chamber (20) and fed with a mixture of air and gas; a radio-frequency electromagnetic radiation source (11) configured to selectively irradiate the combustion chamber (20) with radio-frequency electromagnetic radiations having a given frequency (F) and a given amplitude (A); at least one detecting sensor (13) configured to detect at least one parameter indicative of the presence of flame instability phenomena inside the combustion chamber (20); and at least one control device (12) configured to selectively activate the electromagnetic radiation source (11) and regulate the frequency (F) and/or the amplitude (A) of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source (11) on the basis of the data detected by the at least one detecting sensor (13).

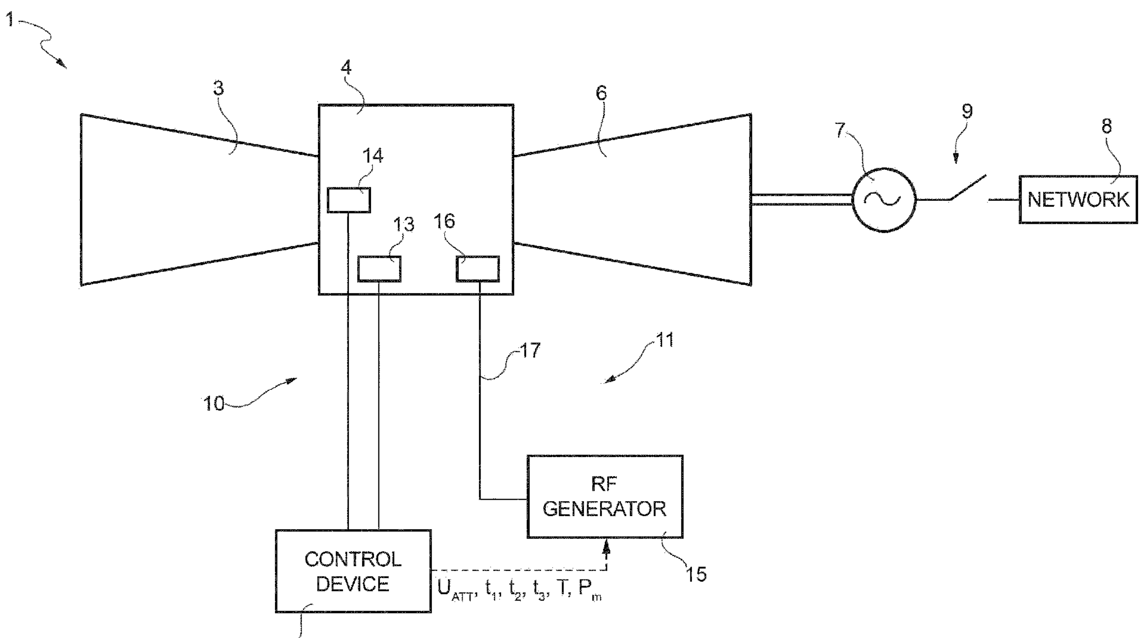

FIG. 1

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from Italian Patent Application No. 102017000081329 filed on July 18, 2017.

[0002] The present invention relates to a gas turbine plant for the production of electrical energy.

[0003] In recent years, under the pressure of increasingly stringent regulations in terms of emissions of polluting substances, combustion techniques have been oriented towards the use of the so-called "lean premix" technology, which provides for the use of burners in which the fuel is premixed with air before being burned. Burners of this type, therefore, are configured to burn lean fuel mixtures.

[0004] In combustion chambers of this type in which lean fuel mixtures are burned, at high powers, acoustic oscillations may be triggered spontaneously (here and hereinafter identified with the term 'humming' typically used in the sector of reference), which are destructive to the structural integrity of the combustion chamber.

[0005] Moreover, due to the reduction in fuel concentration, further flame instability phenomena may occur in combustion chambers of this type. For example, sudden and excessive flame displacements and even intermittent extinguishing of the flame can occur. These flame instability phenomena, as a whole, are normally identified with the term "Lean Blow Out" (here and hereinafter abbreviated as 'LBO', also typically used in the sector of reference).

[0006] The Lean Blow Out is extremely damaging for the plant as it can even lead to repeated and prolonged extinguishing and relighting of the flame in the combustion chamber with evident losses in terms of productivity and reliability of the plant itself.

[0007] In order to prevent the triggering of these undesirable events, the percentage content of fuel is generally increased.

[0008] This technique, however, has the disadvantage of substantially increasing the emissions of polluting substances. For example, in some combustion chambers, even an increase as low as 4% of the fuel concentration in the flame-firing mixture can lead to a 25% increase in NO_x emission.

[0009] Moreover, the increase in the percentage content of fuel is usually achieved by adjusting the opening of the fuel supply valves. However, these valves are subject to mechanical wear. Accordingly, the long-term reliability of the prior art is also compromised.

[0010] It is therefore an object of the present invention to suppress any humming and LBO phenomena without increasing the emissions of polluting substances.

[0011] It is therefore an object of the present invention to provide a gas turbine plant for the production of electrical energy in which any humming and LBO phenomena in the combustion chamber are reduced and which, at the same time, is reliable, simple to produce and able to comply with the limits set by the law relating to the emission of pollutants.

[0012] In accordance with these objects, the present invention relates to a gas turbine plant for the production of electrical energy comprising:

- at least one combustor provided with a combustion chamber in which, in use, combustion occurs, and with at least one burner assembly facing the combustion chamber and fed with a mixture of air and gas;
- a radio-frequency electromagnetic radiation source configured to selectively irradiate the combustion chamber with radio-frequency electromagnetic radiations having a given frequency and amplitude;
- at least one detecting sensor configured to detect at least one parameter indicative of the presence of flame instability phenomena inside the combustion chamber;
- at least one control device configured to selectively activate the electromagnetic radiation source and regulate the frequency and/or the amplitude of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source on the basis of the data detected by the at least one detecting sensor.

[0013] Advantageously, the irradiation of the inner chamber with radio-frequency electromagnetic radiations decreases any humming and LBO phenomena without increasing the emissions of polluting substances and in a reliable manner.

[0014] In fact, the radio-frequency electromagnetic radiations generated by the radiation source interact with the flame at the output of the burner assembly causing an increase in the flame speed.

[0015] Here and hereinafter, the term flame speed means the speed with which the flame propagates in a stationary fluid.

[0016] Typically, when lean fuel mixtures are burned, the flame speed in the combustion chamber of a gas turbine is relatively low.

[0017] Thanks to the present invention, the flame speed is increased not by an increase in the percentage content of fuel, as achieved with the prior art methods, but rather by the flame interacting with the electromagnetic waves generated by the radiation source.

[0018] In fact, the flame has a small number of free electrons. Each free electron absorbs a respective fraction of the power of the electromagnetic radiation incident on the flame. This power is then released by the electrons when they collide.

[0019] In addition, the power of the radio-frequency electromagnetic radiation is only absorbed in the hottest area of the gas present in the combustion chamber, i.e. precisely where the flame is. In fact, it is in this area that the number of free electrons responsible for the absorption of the radio-frequency power is maximum.

[0020] The power thus dissipated can induce flame heating or a change in the kinetics of the chemical reactions occurring in the flame. In both cases, the flame speed increases without an increase in the emissions of polluting substances.

[0021] This flame speed increase can promote the suppression of the humming and/or LBO phenomena.

[0022] The humming phenomenon, in fact, mainly affects flames with low fuel content, i.e. with relatively low flame speed values. For example, humming increases as the ambient humidity increases, and hence the water vapour content of the mixture feeding the flame, with a consequent reduction in the flame speed. Increasing the flame speed is therefore equivalent to dealing with flames that are more stable in terms of humming.

[0023] Moreover, the humming phenomenon arises when the oscillations of the combustion power and the pressure oscillations of the flame are in phase. Said phase depends on the shape of the flame, which in turn depends on the flame speed for a given flow field of the fluid.

[0024] In addition, the power of the acoustic oscillations in the combustion chamber is supplied by exothermic reactions that occur during combustion.

[0025] In accordance with Le Châtelier's principle, any action that leads to the heating of a flame from the outside tends to favour the endothermic reactions at the expense of the exothermic reactions.

[0026] Therefore, the heating of the flame by irradiation with radio-frequency electromagnetic radiations tends to suppress the humming.

[0027] The reduction of the humming phenomenon by applying radio-frequency is supported by experimental evidence.

[0028] Moreover, the application of radio-frequency to a flame reduces the fuel percentage minimum value below which a flame is subject to LBO. Experimental evidence has in fact shown that applying radio-frequency to a flame having a given percentage of fuel and subject to LBO can suppress the latter.

[0029] Furthermore, thanks to the present invention, the plant comprises a control device configured to regulate the frequency and/or the amplitude of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source on the basis of the data detected by the at least one detecting sensor. In this way, the frequency and/or amplitude of the electromagnetic radiations that irradiate the combustion chamber is adjusted so as to optimize the LBO and/or humming reduction.

[0030] Further features and advantages of the present invention will be apparent from the following description of a non-limiting embodiment thereof, with reference to the figures of the accompanying drawings, wherein:

- Figure 1 is a schematic view of a gas turbine plant according to the present invention;
- Figure 2 is a diagram relating to the operation of a detail of the plant in Figure 1;
- Figure 3 is a side view, with parts in section and parts removed for clarity, of a further detail of the plant in Figure 1.

[0031] In Figure 1, reference number 1 indicates a gas turbine plant for the production of electrical energy.

[0032] The plant 1 comprises a compressor 3, a combustor 4, a gas turbine 6 and a generator 7, which converts the mechanical power supplied by the turbine 6 into electrical power to be supplied to an electrical network 8, which is connected to the generator 7 by a switch 9.

[0033] The plant 1 also comprises a stabilizing device 10, which comprises a radio-frequency electromagnetic radiation source 11, a control device 12 and at least one sensor 13.

[0034] The electromagnetic radiation source 11 is configured to irradiate the combustor 4 with radio-frequency electromagnetic radiations.

[0035] In particular, the electromagnetic radiation source 11 comprises a generator 15 configured to generate electromagnetic radiations, at least one antenna 16 configured to irradiate electromagnetic radiations, and at least one radio-frequency power cable 17, configured to supply the electromagnetic radiations generated by the generator 15 to the antenna 16.

[0036] Preferably, the generator 15 is a free electron vacuum tube (generally called klystron) configured to generate radio-frequency electromagnetic radiations (RF).

[0037] In particular, the generator 15 is configured to generate electromagnetic radiations with frequencies ranging between 1-10 GHz, preferably between 3 and 4 GHz, and in particular of 3.7 GHz.

[0038] With reference to the diagram in Figure 2, the generator 15 is configured to generate pulse trains.

[0039] As we will see in detail later, the pulse trains are generated by the generator 15 with a frequency F=1/T.

[0040] Each pulse train has a total time length tD. Preferably, the time length tD is shorter than a crossing time tA, which is understood as the time it takes the air-fuel mixture to cross the flame. This prevents the motion of the mixture crossing the flame from dragging outside of the flame the power dissipated within the flame following irradiation with radio-frequency electromagnetic radiations.

[0041] In the non-limiting example described and illustrated herein, the crossing time tA is approximately one millisecond.

[0042] Each pulse train may comprise more than one pulse.

[0043] Each pulse has a given power P and a given time length t1.

[0044] Within the same pulse train, the pulses follow one another at regular time intervals having a t2 time length.

[0045] Each pulse train is separated from the next by a time interval t3 having a time length such as to meet the following relation:

$$tD = T - t3$$

[0046] The total number of pulses N in a pulse train can be calculated according to the following relation:

$$N = (tD+t2)/(t1+t2)$$

[0047] The power P of each pulse is preferably the maximum power that can be generated by the generator 15, compatibly with the cooling requirements of the antenna 16.

[0048] The mean power Pm of each pulse train can be calculated using the following relation:

$$Pm = P \cdot t1 \cdot N/tD$$

[0049] During irradiation, the flame absorbs only a small fraction of the power radiated by the radiation source 11.

[0050] Therefore, the radiation source 11 dissipates a power Pdiss that can be calculated, in an approximate way, in accordance with the following relation:

$$Pdiss = Pm \cdot tD /(tD+t3)$$

[0051] Preferably, a maximum allowable value of dissipated power Pdiss is set, which is calculated on the basis of the cooling system available for the electromagnetic radiation source 11. The lower the value of the dissipated power Pdiss, the less the need for specific cooling systems, which are difficult and expensive to manufacture.

[0052] For these reasons, the dissipated power Pdiss is preferably controlled in order to ensure the smooth operation of the plant 1.

[0053] With reference to Figure 1, the plant comprises at least one detecting sensor 13 configured to detect flame instability (LBO) in the combustor 4, and preferably also at least one additional detecting sensor 14 configured to detect the presence of acoustic oscillations (humming) in the combustor 4.

[0054] With reference to Figure 1, the detecting sensor 13 is configured to detect at least one parameter indicative of the presence of flame instability phenomena in the combustor 4.

[0055] Preferably, the detecting sensor 13 is a sensor selected from the group of sensors comprising:

- chemiluminescence intensity sensors capable of detecting the intensity of the ultraviolet OH-radical emissions linked to the chemical reactions that occur in the combustor. The ultraviolet OH-radical chemiluminescence remains advantageously intense even for flames that are particularly low in fuel.
- flame colour sensors, such as CCD sensors; in fact, if the flame is subject to LBO, its colour can turn from red to blue);
- temperature sensors, such as thermocouples, ohmmeters, adjustable laser diodes, etc.;
- sensors configured to detect changes in the electrical conductivity of the flame. For example, an ionization sensor sufficiently effective in the present case is the one based on the application of a voltage difference across the flame, or a part of it, by means of at least two electrodes.

[0056] In the non-limiting example described and illustrated herein, the detecting sensor 13 is a chemiluminescence sensor capable of detecting the concentration of OH^- ions.

[0057] A non-illustrated variant provides that the plant comprises more than one detecting sensor, each of which detects a different parameter. This redundancy can make the detection of flame instability phenomena more reliable.

[0058] Preferably, the detecting sensor 13 detects a time course of the parameter indicative of the presence of flame instability phenomena in the combustor 4.

[0059] Preferably, the additional detecting sensor 14 is a pressure sensor, for example a piezoelectric sensor or a microphone.

[0060] The detecting sensor 13 and the optional additional detecting sensor 14 transmit the detected data to the control device 12.

[0061] The control device 12 is configured to selectively activate the generator 15 by means of a UATT activation signal if the detecting sensor 13 detects an activation condition indicative of the presence of flame instability phenomena (LBO) in the combustor 4.

[0062] Preferably, the activation condition may occur when the indicative parameter detected by the detecting sensor 13 exceeds or falls below a predetermined threshold or when the time course of the indicative parameter detected by the detecting sensor 13 shows a given pattern.

[0063] In the non-limiting example described and illustrated herein, the activation condition occurs when the OH radical chemiluminescence signal drops below 30% of its mean value and for at least 10 milliseconds does not rise above 120% of its mean value (a condition identifying an extinguishing event).

[0064] Alternatively, it is possible to identify a combined activation condition of two different parameters: the chemiluminescence signal and the acoustic signal.

[0065] In this case, the activation condition occurs when a peak in the OH radical chemiluminescence signal and a sufficiently significant peak in the acoustic signal occur substantially at the same time (a situation identifying relighting) and/or when the OH radical luminescence signal is substantially close to zero and the acoustic signal is less than a given threshold value (a situation identifying extinguishing). These activation conditions are linked to the fact that LBO phenomena are characterised by a succession of extinguishing and relighting events.

[0066] A non-illustrated variant provides that the control device 12 is configured to selectively activate the generator 15 by means of a UATT activation signal even if the additional detecting sensor 14 detects a further predefined activation condition indicative of the presence of thermoacoustic oscillations in the combustor 4 (humming).

[0067] For example, a further activation condition can occur when the pressure detected by the additional detecting sensor 14 exceeds a predetermined threshold value, for example 20 mbar.

[0068] In case both the detecting sensor 13 and the additional detecting sensor 14 are operating, the generator 15 is activated when the activation condition and/or the further activation condition is detected.

[0069] In the non-limiting example described and illustrated herein, in order to identify the occurrence of the activation condition, the control device 12 can use different data processing algorithms, such as for example those based on 'wavelets', the 'Fast Fourier Transform', neural networks, spectral or statistical methods. For example, the control device 12 can be configured to count the pairs of extinguishing and relighting events detected per time unit.

[0070] The control device 12 is further configured to regulate the frequency F and/or the amplitude A of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source 11 on the basis of the data detected by the detecting sensor 13. Preferably, the control device 12 is further also configured to calculate the mean power Pm of each pulse train on the basis of the data coming from the detecting sensor 13.

[0071] Preferably, the frequency F and the mean power Pm are calculated by the control device 12 also on the basis of the data detected by the additional detecting sensor 14.

[0072] The control device 12 establishes the values t1, t2 and t3, required for optimal stabilization, on the basis of the mean power Pm and the frequency F.

[0073] In the non-limiting example described and illustrated herein, the values of the parameters thus calculated are: T=10 milliseconds, t1=33 microseconds, t2=450 microseconds, t3=9 milliseconds, tD=1 millisecond, N=3, P=1 MW, Pm=100 kW, Pdiss=10 kW.

[0074] The values of the time T, the mean power Pm and the time lengths t1, t2, t3 calculated by the control device 12 are then fed to the radio-frequency electromagnetic radiation source 11.

[0075] The radio-frequency electromagnetic radiation source 11 then generates the pulse trains according to the input Pm, t1, t2, t3 and T data.

[0076] In this way, the pulse train generated by the generator 15 is synchronized with the acoustic oscillations in the combustor 4 so as to maximize the absorption of the electromagnetic radiations when the flame temperature is maximum.

[0077] Figure 3 shows a part of the combustor 4.

[0078] In the non-limiting example described and illustrated herein, the combustor 4 is provided with a combustion chamber 20 in which combustion occurs, an outer chamber 21 (also called plenum), in which compressed air flows from the compressor 3, and at least one burner assembly 22 facing the combustion chamber 20 and supplied with fuel and with the air flowing into the outer chamber 21.

[0079] Preferably, the burner assembly 22 is provided with a premix burner and a pilot burner (not shown in the attached Figure 3).

[0080] The combustion chamber 20 is covered with a plurality of substantially rectangular tiles 24 arranged in adjacent columns. The tiles 24 are made of a refractory material, which is transparent to radio-frequency electromagnetic radiations.

[0081] The antenna 16 is preferably installed behind one of the plurality of tiles 24. Preferably, the antenna 16 is coupled to the "cold" rear face of the tile of the plurality of tiles 24.

[0082] In particular, the antenna 16 has dimensions substantially the same as the dimensions of the tile 24 coupled thereto, and therefore is rectangular.

[0083] In this configuration, the tile 24 coupled to the antenna 16 and the tiles 24 adjacent thereto thermally protect the antenna 16, thus guaranteeing its durability over time.

[0084] A second embodiment, not shown in the attached figures, provides that the antenna 16 is positioned close to the pilot burner of the burner assembly 22.

[0085] In use, if the detecting sensor 13 and/or the additional detecting sensor 14 detect an activation condition and/or a further activation condition, respectively, the generator 15 is activated by the control device 12 through the UATT signal.

[0086] The generator 15 then generates a pulse train at a frequency F and in accordance with the time lengths t1, t2, t3 and the mean power Pm calculated by the control device 12.

[0087] The antenna 16 irradiates the combustion chamber 20 with the electromagnetic radiations generated by the generator 15.

[0088] The electromagnetic radiations interact with the flame at the output of the burner assembly 22 causing an increase in the flame speed.

[0089] As already mentioned above, the main effect of the increased flame speed is a significant reduction of the LBO and humming phenomena.

[0090] Therefore, the plant made in accordance with the present invention achieves a significant reduction of the LBO and humming phenomena without necessarily requiring an increased percentage of fuel to be supplied to the burner assembly 22, and therefore without increasing the emissions of polluting substances. Moreover, the plant according to the present invention has no mechanical wear problems, as was the case in the solutions of the prior art.

[0091] The reduction of the LBO and humming phenomena leads to a significant reduction in maintenance costs. In fact, to carry out repair operations for damage caused by the LBO and humming phenomena, the plant 1 is shut down and energy production is stopped for the time necessary to carry out the repair operations.

[0092] In addition, the radio-frequency electromagnetic radiations used in the present solution have intensities that do not induce dangerous electrical phenomena, such as electric arcs or corona effects within the combustor 4.

[0093] A further advantage of the present invention is that the antenna 16 power supply is pulsed.

[0094] First of all, the pulsed power supply allows the frequency of the radio-frequency electromagnetic radiations to be adjusted so as to maximize their absorption in the flame.

[0095] The pulsed power supply also enables very high peak values of the radio-frequency power, with a consequent greater stabilizing effect on the flame, while maintaining a sufficiently low mean power level such as not to require the use of systems for cooling the generator 15 and the antenna 16, which are difficult and expensive to manufacture.

[0096] Moreover, the relatively modest values of the power required by the generator do not significantly change the energy balance of the plant.

[0097] Lastly, the compactness of the stabilizing device 10 allows installation even on existing plants. The linear dimensions of the antenna 16 and the generator 15 are in fact approximately 20 cm and 1 m, respectively, and the generator 15 can be installed outside the combustor 4.

[0098] Lastly, it is clear that modifications and variations may be made to the plant described herein without departing from the scope of the appended claims.

Claims

1. A gas turbine plant for the production of electrical energy comprising:

   - at least one combustor (4) provided with a combustion chamber (20) in which, in use, combustion occurs, and with at least one burner assembly (22) facing the combustion chamber (20) and fed with a mixture of air and gas;
   - a radio-frequency electromagnetic radiation source (11) configured to selectively irradiate the combustion chamber (20) with radio-frequency electromagnetic radiations having a given frequency (F) and a given amplitude (A);
   - at least one detecting sensor (13) configured to detect at least one parameter indicative of the presence of flame instability phenomena inside the combustion chamber (20);
   - at least one control device (12) configured to selectively activate the electromagnetic radiation source (11) and regulate the frequency (F) and/or the amplitude (A) of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source (11) on the basis of the data detected by the at least one detecting sensor (13).

2. The plant according to claim 1, wherein the detecting sensor (13) is configured to detect a time course of the at least one parameter indicative of the presence of flame instability phenomena inside the combustion chamber (20).

3. The plant according to claim 2, wherein the control device (12) is configured to calculate the frequency and/or the amplitude of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source (11) on the basis of the time course of the at least one indicative parameter detected by the at least one detecting sensor (13).

4. The plant according to any one of the foregoing claims, wherein the detecting sensor (13) is a sensor selected from the group of sensors comprising:

   - chemiluminescence intensity sensors;
   - flame colour sensors;
   - temperature sensors;
   - sensors for the electric conductivity of the flame.

5. The plant according to any one of the foregoing claims, wherein the detecting sensor 13 is an OH radical chemiluminescence intensity sensor.

6. The plant according to any one of the foregoing claims, comprising at least one further detecting sensor (14) configured to detect at least one further parameter indicative of the presence of acoustic oscillations in the combustion chamber (20); the control device (12) being configured to regulate the frequency (F) and/or the amplitude of the radio-frequency electromagnetic radiations irradiated by the electromagnetic radiation source (11) also on the basis of the data detected by said further detecting sensor (14).

7. The plant according to claim 6, wherein said further detecting sensor (14) is a pressure sensor.

8. The plant according to any one of the foregoing claims, wherein the radio-frequency electromagnetic radiation source (11) comprises a generator (15)

configured to generate pulse trains at the frequency (F); the pulse trains being associated with a mean power (Pm); each pulse of the pulse train being associated with a power (P); the control device (12) being configured to regulate the mean power (Pm) on the basis of the data detected by the at least one detecting sensor (13).

9. The plant according to claim 8, wherein each pulse train comprises a number of pulses (N) calculated on the basis of the mean power (Pm) and the power (P) associated with each pulse.

10. The plant according to claim 8 or 9, wherein each pulse train comprises a plurality of pulses having a first time length (t1); the control device (12) being configured to calculate the first time length (t1) of each pulse on the basis of the mean power (Pm).

11. The plant according to any one of the claims from 8 to 10, wherein each pulse train comprises a plurality of pulses which follow one another at regular time intervals having a second time length (t2); the control device (12) being configured to calculate the second time length (t2) on the basis of the mean power (Pm).

12. The plant according to any one of the claims from 8 to 11, wherein each pulse train is separated from the next pulse train by a time interval having a third time length (t3); the control device (12) being configured to calculate the third time length (t3) on the basis of the mean power (Pm).

13. The plant according to any one of claims from 8 to 12, wherein each pulse train has a total time length (tD); the total time length (tD) being shorter than the crossing time (tA), which is understood as the time it takes the air-fuel mixture to cross the flame.

14. The plant according to any one of the foregoing claims, wherein the electromagnetic radiation source (11) comprises an antenna (16) connected to the generator (15) and arranged so as to irradiate the combustion chamber (20).

15. The plant according to claim 14, wherein the antenna (16) is coupled to a tile (24) of a plurality of tiles (24) which cover the combustion chamber (20).

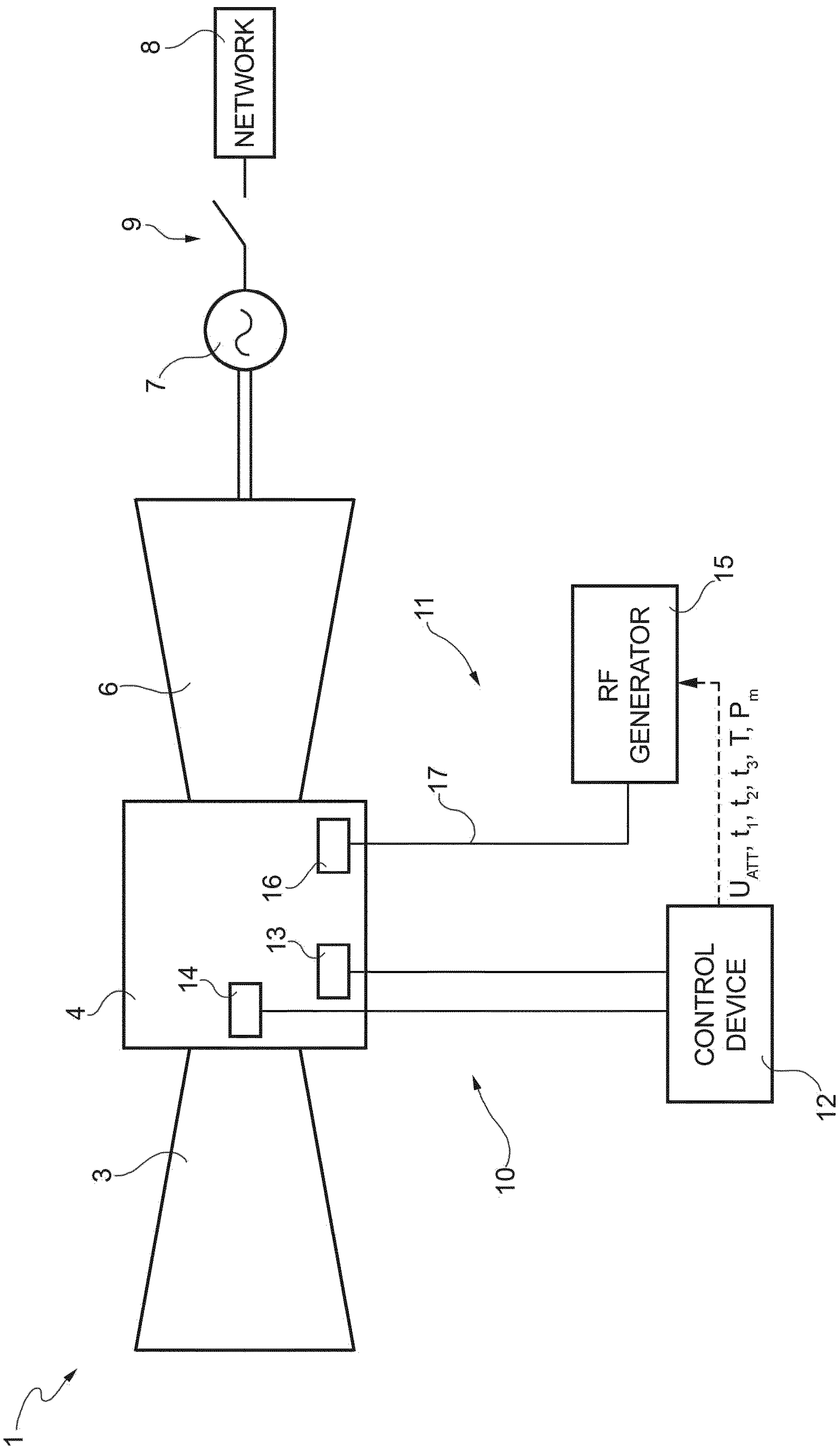

FIG. 1

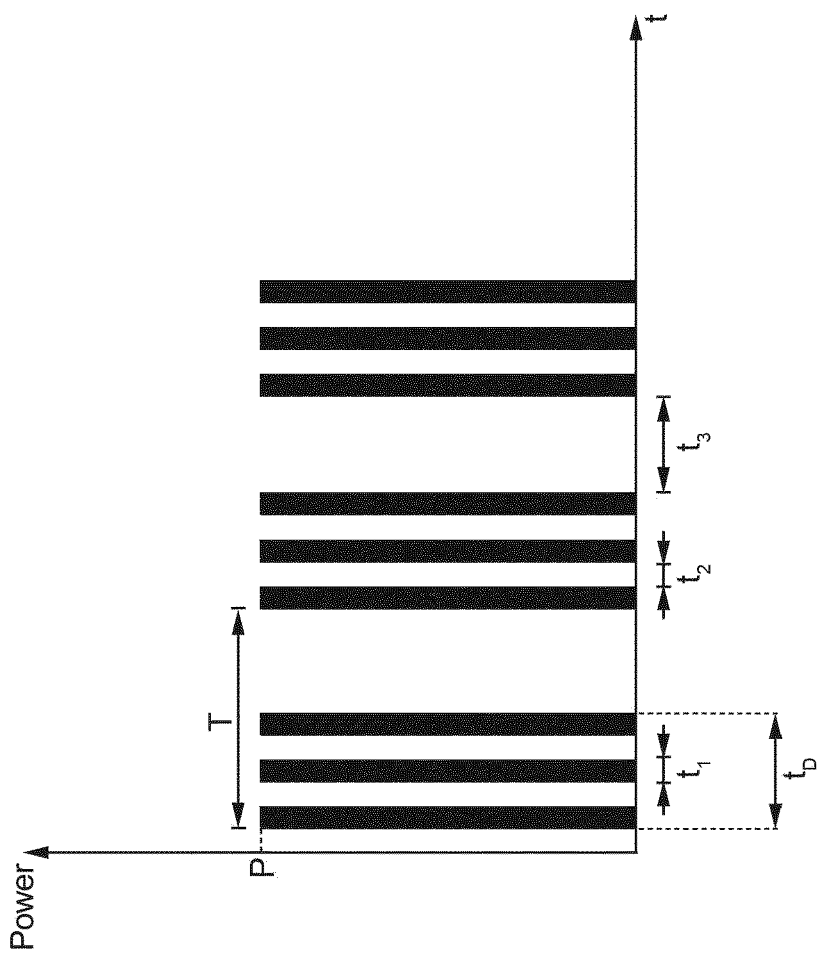

FIG. 2

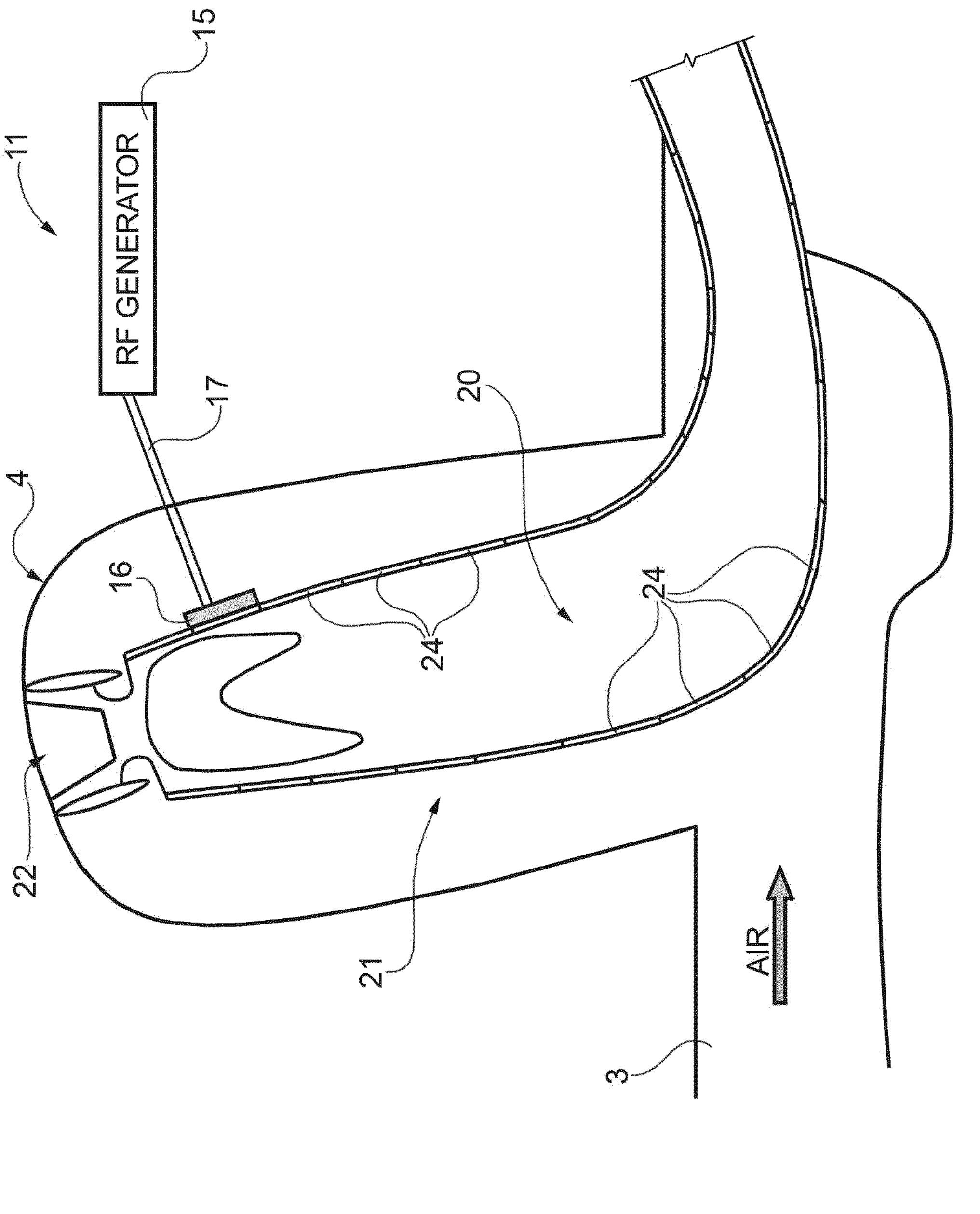

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 18 18 4118

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	Andrea Di Vita: "On Rayleigh's criterion of thermo-acoustics", , 21 March 2016 (2016-03-21), pages 234-272, XP055463118, Genova Retrieved from the Internet: URL:https://www.researchgate.net/profile/Andrea_Di_Vita/publication/304495257_On_Rayleigh%27s_criterion_on_thermo-acoustics_-_A_Di_Vita%27s_PhD_thesis/links/5771400308ae842225ac0e23/On-Rayleighs-criterion-on-thermo-acoustics-A-Di-Vitas-PhD-thesis.pdf [retrieved on 2018-03-27] * paragraph [15.3] - paragraph [15.4] * * figure 15.37 * -----	1-3, 6-12,14, 15	INV. F23R3/18 F23N5/24
X	EMANUEL STOCKMAN ET AL: "Pulsed Microwave Enhancement of Laminar and Turbulent Hydrocarbon Flames", 45TH AIAA AEROSPACE SCIENCES MEETING AND EXHIBIT, 8 January 2007 (2007-01-08), XP055463312, Reston, Virigina DOI: 10.2514/6.2007-1348 ISBN: 978-1-62410-012-3 * paragraphs [000B], [000C] * * figures 8,9,10 * -----	1-3,6-12	

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TECHNICAL FIELDS SEARCHED (IPC)
F23R
F23N

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	7 November 2018	Burattini, Paolo

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 4118

DOCUMENTS CONSIDERED TO BE RELEVANT

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X	ANDREAS EHN ET AL: "Setup for microwave stimulation of a turbulent low-swirl flame", JOURNAL OF PHYSICS D: APPLIED PHYSICS, INSTITUTE OF PHYSICS PUBLISHING LTD, GB, vol. 49, no. 18, 8 April 2016 (2016-04-08), page 185601, XP020303716, ISSN: 0022-3727, DOI: 10.1088/0022-3727/49/18/185601 [retrieved on 2016-04-08]	1-12	
A	* figures 5,6,7 * * page 7 * -----	13	

TECHNICAL FIELDS SEARCHED (IPC)

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1

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Patent documents cited in the description

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