values. Another solution is to measure the thrust in the reference frame of the sail, that is to say in the axis of the sail and in the axis at right angles to the sail. It will then be necessary to know the angle of the sail with respect to the ship, so as to bring the forces into the axis of the sail and at right angles to the sail (reference frame of the sail) back into thrust force and drift force in the reference frame of the ship. As for the regulation of the pressure difference between the outside and the inside of the sail, in the case of an inflatable sail, this pressure difference can be measured by a differential pressure sensor and set by a set pressure difference setpoint, i.e. servocontrolled by taking account for example of the force and direction of the wind, of the variations of force and direction of the wind (ratio between max value and min value), on the state of the sea for example. The inflation system can for example be produced with fans. Fans are regulated in order to achieve the pressure difference setpoint between the inside and the outside of the wing.

[0039] Using a closed-loop control or regulation system allows an optimization of the efforts and, using the values supplied by the effort sensors, quantification of the gain in lowering CO_2 emission.

[0040] As **Figure 3** shows, the computation algorithm with which the ship according to the invention is equipped can calculate an incidence angle setpoint of the wing (or inflatable sail), a wing (or inflatable sail) surface area setpoint and a wing (or inflatable sail) differential pressure setpoint, according to an open-loop control system, based on conversion tables for example, for a desired thrust value. These setting values (incidence angle setpoint of the wing, a wing surface area setpoint and a wing differential pressure setpoint) remain the same, if for example the wing were torn or damaged, because it does not involve a measurement of the result.

[0041] In an open-loop control system, it is possible to act on the regulation of the pressure for example, in the case of an inflatable sail, by regulating a speed of rotation of the fans, which will correspond to a certain pressure difference (speed - pressure equivalence table) for the pressure difference between the inside of the sail and the outside. If the fan is mounted without propeller, the pressure will not be good, and it will not be seen. There are nevertheless other means that make it possible to check this kind of problem, such as, for example, monitoring of the engine current associated with a certain speed.

[0068] The advantage of acting on the angle is that it is a fast operation that requires little energy. When the wind is changing for example, this is the manoeuvre to be used.

[0069] It may also be very advantageous to reduce the sail surface area by reefing, so as to simultaneously reduce the surface area of the sail and the height of the centre of aerodynamic thrust. This operation will make it possible, once reefed, to reduce the drift effort, so as to remain within acceptable drift values and, if necessary, reef again, or completely lower the wing (or the sail).

[0070] To lower the sail, the same operation as that of reefing is used.

[0071] Once the sail is lowered, it is possible to place it in the axis of the boat in order to manually or automatically lock the rotation of the sail. It then has to be protected from external attacks by manually or automatically reclosing the top part of the sail receptacle. The electronic control and power systems can then be shut down.

[0072] Upon malfunction, various situations can occur. Some of them are explained hereinbelow:

[0073] **Power supply completely cut with the sail in operation**: in this case, the sail steering motor (incidence) is set free to rotate, and the sail will be feathered face to the wind. The fans are shut down, but the dynamic air intake continues to supply the sail with a sufficient pressure which prevents the wing from luffing. The sail will remain thus, with the sail surface in position, the sail remaining permanently face to the wind (minimization of the efforts).

[0074] **Fault of the open regulation loop sensors** and essentially wind speed and direction: the closed regulation loop takes over on its own.

[0075] **Fault of the sensors of the closed regulation loop**: the open regulation loop takes over on its own.

[0076] **Malfunctioning of both regulation loops**: leave the sail to come itself face to the wind, which minimizes the efforts on it. That amounts to being the same as completely cutting the electrical power supply of the sail, except if the fans can still be actuated without any danger. A separate emergency power supply of the fans can be used.

[0077] **Loss of actuators**:

[0078] *Loss of the fans*: As there are several fans, it should be possible to power them separately so as not to lose all of them. However, that can nevertheless occur. In this case, the dynamic inflation of the sail will prevent it from luffing and allow the sail to be lowered without risk, until the fans are repaired.

[0079] *Loss of the actuators used for hoisting or lowering the sail*: If it is possible to lower but not hoist, this is not a problem. It is sufficient to lower the wing to make it safe.

[0080] Conversely, if it is not possible to lower, that will depend on what is blocked. If, for example, the sail guidance line is no longer operating, it will still be possible to lower, but that will require a manual intervention so as to stow the wing correctly. The same applies if a reefing no longer operates. However, if the mast no longer lowers, there is a manual solution to actuate the motor. By contrast, if it is the pipes which are seized, it is possible that one or two elements no longer retract. It will then be possible to haul in all the other elements so as to intervene on the blocked elements at an acceptable height.

[0081] If the mast remains truly blocked when completely deployed, it is possible to leave the sail face to the wind so as to minimize the efforts.

[0082] *Loss of the actuator setting the angle of the sail*: In the event of loss of the control of the mast angle actuator, the incidence system is automatically set to free mode, which provokes the feathering of the sail face to the wind. It could however be that the actuator is blocked, and that then the sail is located at a fixed angle, which could be hazardous depending on the wind conditions. If it is possible to go with the boat to an angle which means that the sail is face to the wind, that makes it possible to lower the sail. The case of all sailboats with conventional sails then applies, in which the large sail must be hoisted or lowered while face to the wind. The other solution in the case where it is not possible or not desirable to divert the ship from its route, is that it is possible to have a manual disconnection system, or even a fusible element in the effort transmission chain, which will free the sail to allow it to go face to the wind.

Example 1

[0083] The CO_2 gains can go from 100% of the consumption of the ship (in the case where there is a switch to an entirely sail propulsion mode such as NEOLINE) to 0% if