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Active Control for the Operational Safety of Control-Towers

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Summary

Operator's comfort in control towers can be troubled by the oscillations induced by winds and moderate earthquakes with consequences on the safety of the air traffic. An active control system, inserted at the top of the tower, can reduce the movements. Results of numerical simulations carried out on a sample tower, show that the effects of wind induced motion can be lowered below the satisfactory threshold and, when moderate earthquakes act, the response remain under the tolerability limit.

Keywords: Active and hybrid control; operator comfort; operational safety; wind; earthquake.

1. Abstract

The typical structural scheme of control towers (inverse pendulum) make them very sensitive to lateral dynamic actions. Depending on the frequency content and the acceleration values, induced lateral oscillations can trouble the operators jeopardising the appropriate progress of operations with risk for the air traffic safety.

Wind induced oscillations usually go on for a long time provoking discomfort and loss of attention. Short motions, like earthquakes of moderate intensity, not damaging structures nor endangering human life, can induce anxiety, fright, or even panic. Human perception of motion depends on acceleration, for short duration motions, and on acceleration variation, for a long excitation. The reduction of those response parameters limits perception.

ENAV (Ente Nazionale Assistenza al Volo), the Italian authority supervising the air traffic, pointed out the problem of providing a proper security to tower operators when lateral oscillations occur. The use of active control systems, already tested or installed on high buildings, was suggested for the high efficiency in reducing the response of systems characterised by a dominant frequency. Numerical simulations of the effect of a hybrid control system installed at the top of a typical control tower, aiming at reducing or eliminating the discomfort, have been carried out.

A typical configuration, reported in Figure 1, was suggested by ENAV to simulate the behaviour of a tower equipped with a hybrid control system. The mass values resulting from the load analysis are: 509 t for the service block, 350 t for the control block and 26 t/m for the column. The fundamental tower frequency results 0.606 Hz. A hybrid control device, shown in Figure 2, is

located at the top of the tower. The system consists of a mass (92.6 t) sliding long two normal directions, tuned (0.57 Hz) to the fundamental frequency of the structure. Forces can be applied through a couple of actuators controlled by a controller. Steel springs and viscous oleo-dynamic dampers allow the suitable values of damping (92 kN·s/m) and stiffness (1187 kN/m) for the system. Sensors provide information on the input excitation and the structure response used by the controller to modify the response on the basis of the pre-defined set-point. The main characteristics of the hydraulic plant, resulting from the numerical computations, are: effective power = 160 kW, supply pressure = 315 bar, nominal delivery capacity = 360 l/min, accumulator capacity = 1000 l (enough for 30 s of supply).

The control system is designed to function according to the linear quadratic optimum control algorithm. Numerical simulations are carried out on a 2 DOF system. Lateral actions are simulated through four artificially generated time histories of both wind speed (duration = 600 s, average speed = 35 m/s, maximum speed = 50 m/s, Simiu's power spectral density) and ground acceleration (duration = 25 s, PGA=0.5 m/s^2, Eurocode response spectrum).

Results show that the r.m.s. of the response acceleration under wind excitation can be maintained under the satisfactory limit for buildings, avoiding discomfort. The average value of the r.m.s. of the response acceleration to the four considered wind speed histories without control is 0.16 m/s^2, this value is at the limit tolerated for an off-shore platform but eight times greater than the building limit. 0.03 m/s^2 is the value, below the satisfactory threshold, obtained with active control. If the device performs in passive mode its effect is reduced but still effective: 0.059 m/s^2.

Panic states can be avoided, when moderate earthquakes occur. The hybrid control system reduces the maximum value of the response acceleration from 1.03 m/s^2, which is intolerable, to 0.46 m/s^2, below the annoying limit. It is requested a higher power than in the case of wind.

The performances are provided by a system characterised by values of mass, forces, power, which can be supplied by normal equipment.

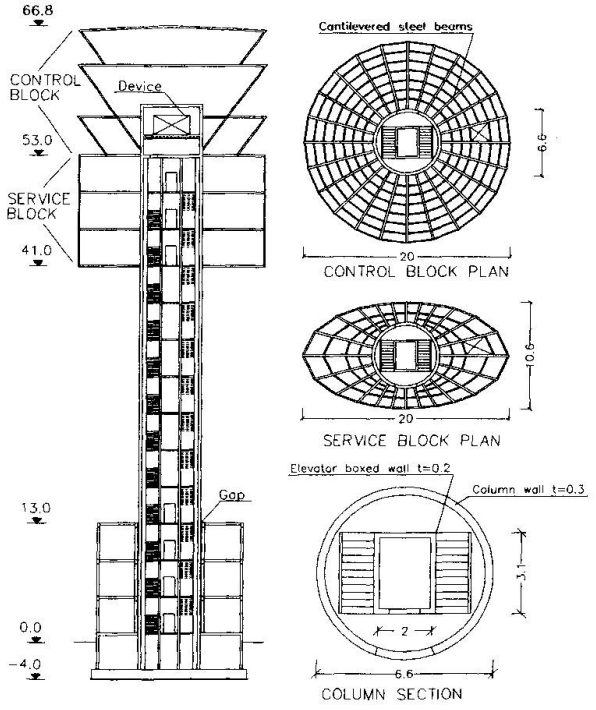

Fig.1 – Sample tower

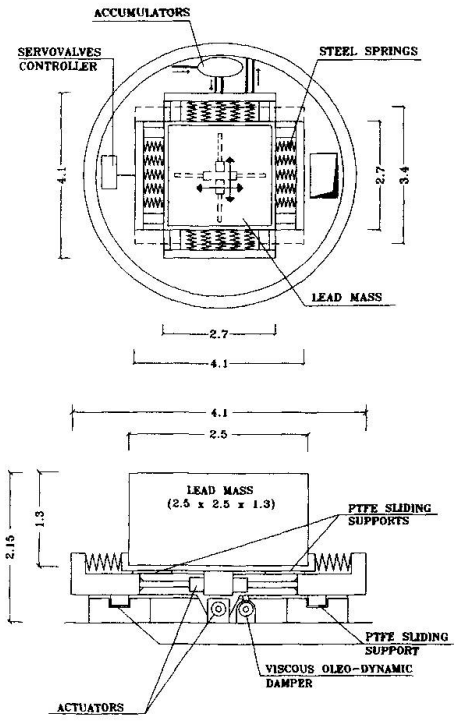

Fig.2 Control device