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ACTIVE CONTROL OF A RTV CENTER

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ABSTRACT

The dynamic behaviour of a RTV Centre at impulse, wind and seismic loads is studied. A system for automatic control of satellite antenna is proposed. Numerical results for the system with and without active control are compared.

KEYWORDS

FEM tower model; eigen values; antenna equipment control system.

Introduction.

Bulgaria is on one of the first position in Europe concerning the number of radio and television towers per unit area of the territory of the country. More over of fifteen radio and television equipment of tower and mast type are erected, which have been operated successfully till now (Fig.1.). In these engineering equipment, the active elements of their technological fitting-up (like radio, television, radio-relay, radio-telephone, satellite and other communication antennas) on their top part are mounted, on specially built for their location bearing construction antenna supports. The erected in Bulgaria radio and television equipment of tower and mast type have mixed supporting construction - body from reinforced-concrete with ringless or multi-angles cross section and antenna support from solid walled or bar metal construction, on which are hanged the antenna systems. In the natural surroundings of their exploitation servicing, the high tower and thick-walled equipment are put under dynamical excitations of the speed wind pressure, earthquake forces and other impulse and dynamical influences, which from the specific form of the cross sections of the support system, from technological loads and loads from own weight, loading from becoming ice, temperature loading from twenty-four-hour differences, from one-side sun heating and from other kind of complex loading are caused. An essentially important stage of the projecting of this kind equipment are static and dynamical studies. In the projecting process the reliable combinations of loading are obtained, for which the sized cross sections in two stages (strength and deformations) are examined. The results from the check of strength are obligated for the reliability of the construction and the second check is examined the satisfying of the strong conditions of the technological requirements. The montage axis of the radio-relay and satellite antennas must not deviate from the vertical, and for the other antennas, the rotation of the axis no more from 0,5 degree is allowed. The satisfying of the second check of deformations of the antenna support is a difficult engineering problem, which is solved by the value of depositing of the tremendous volumes expensive materials like metal and high strength concretes. Moreover, the results about obtaining the quality radio and television signal do not always account for the extra invested resources. In other cases, some passive dynamical dampers of the antenna supports are used. In the progress of the exploitation, the antenna systems can be directed towards various emitted objects. Every guidance towards new object requires additional adjustment of the antennas. This adjustment, which is connected with tremendous expenses, from the highly skilled specialists is done.

In this paper, an alternative approach for providing of qualitative television and radio signal by means of Control System (CS) of the reaction of the antenna systems related to tremendous dynamical loading on the radio and television installations, and specially on the antenna support, is offered. As an illustrative example, a reinforced-concrete variant of RTV tower in town Plovdiv is solved.

Mathematical description of the tower.

The mathematical description of the construction is given by the systen of differential equations of second order:

$$(1)\quad \begin{bmatrix} M_{yy} & M_{yx} \\ M_{xy} & M_{xx} \end{bmatrix} \begin{Bmatrix} \ddot{Y} \\ \ddot{X} \end{Bmatrix} + \begin{bmatrix} C_{yy} & C_{yx} \\ C_{xy} & C_{xx} \end{bmatrix} \begin{Bmatrix} \dot{Y} \\ \dot{X} \end{Bmatrix} + \begin{bmatrix} K_{yy} & K_{yx} \\ K_{xy} & K_{xx} \end{bmatrix} \begin{Bmatrix} Y \\ X \end{Bmatrix} = \begin{Bmatrix} 0 \\ T \end{Bmatrix}$$

where Y is a vector of unknown displacement, X is a vector of known kinematical moving and T is a vector of unknown dynamical reactions. The blocking in (1) is made according the integration of the vectors Y and X in a generalised vector of moving. If equation (1) is solved in respect of the vector of the unknown moving Y, it will be obtain the equation:

$$(2)\quad [M_{yy}]\{\ddot{Y}\} + [C_{yy}]\{\dot{Y}\} + [K_{yy}]\{Y\} = -[M_{yx}]\{\ddot{X}\} - [C_{yx}]\{\dot{X}\} - [K_{yx}]\{X\}$$

A variant of the construction of RTV tower in town Plovdiv with steel concrete body and lattice metal antenna support is studied (fig.2). The discretization of the construction according the upper equations (1) and (2) is made by the finite elements method. The steel concrete shell is modelled by shell elements, which have 4 nodes and 24 degree of freedom. The plates are modelled by the plate elements with 4 nodes and 12 degree of freedom. The foundation and the bars of the metal grids are modelled by bar elements with 2 nodes and 12 degree of freedom. The membrane elements are with 2 nodes and 12 degree of freedom. The whole number of the degree of nodes is 1 044, from which 861 are shell, plate or membrane and 476 are barm. The whole number of the degree of freedom is 5 868. The influence of the thickness of the wall in the various zone on the deformation of the model is studied. For that purpose three cases are observed:

I. Thickness of the tower wall according the preliminary project. For bend forces t=t-0,06 m.

II. Thickness of the wall for bend forces t=0. m

III. Thickness of the wall in all sections t=0,25 m

For the first two (divisible) eigen frequencies in direction of X (correspondingly Y) are obtain the following values:

Table 1

case	$T_{1,2}$ [s]	$T_{3,4}$ [s]
1	0,478	0,393
2	0,477	0,390
3	0,475	0,376

The first three main forms of tower oscillations in direction of X (correspondingly Y) for case 1 from table 1 are shown in fig.3 and the values of the eigen frequencies are shown in table 2.

Table 2

number of the form	period T[s]	frequency ω [rad/sec]
1 form	0.478	13.14
2 form	0.394	15.95
3 form	0.135	46.71

The obtaining results show that predominates the membrane stiffness of the tower wall. The moving and the forces in some characterised points from the construction are shown in table 3.

<u>Antenna installation control system. Principe solution.</u>

For the main support building constructions to be projected by the classical strength requirements, the quality of the radio and television signal can be reached by construction of SAC for control about dynamical reaction only of antenna devices or antenna support. As dynamical loading on the main building construction, the control system of the antennas will create conversely dynamical excitations. These excitations will secure a relatively immobility of the antenna installations and will not allow to be worsen of the received or emitted signal. The extra invested devices for construction of CS are minimum. The expected results in this approach guarantee a big precision and fast action of dynamical reaction control. This leads to high quality of the radio and television signals and stable and reliable connection.

The dynamical loads on the tower arouse revolution in direction of degree of freedom of the cross section, where is fixed the studied antenna installation, fig.4. The CS must provide stabilisation of the antenna orientation towards the signal source (for example a satellite). For this reason the CS turn the antenna on angle φ_a (t), which must be opposite of the revolution $\varphi_n(t)$:

$$(3) \qquad \varphi_z = -\varphi_n$$

where with φ_z is indicated the desired value of φ_a. Because of the inevitable inexactnesses in the real objects, the real revolution angle is distinguished from the given φ_z, because of that it is obtained a co-ordination error angle of antenna orientation:

$$(4) \qquad \varepsilon = \varphi_z - \varphi_a$$

The scheme of principle of the CS is shown in fig.5. It will be used the following symbols by formulation of its mathematical model:
- u - input amplifier voltage;
- V_y - output amplifier voltage;
- k_y - amplifier gain;
- k_p - potentiometer constant;
- J - moment of inertia reduced to the egine shaft;
- k_c - coefficient of the resistance moment constant;
- k_{dv} - coefficient of the engine moment constant;
- M_c - resistance moment;
- M_{dv} - engine moment.

The equations of the separated links of the scheme of principle are:
- potentiometers:

$$(5) \qquad u = k_p(\varphi_z - \varphi_a)$$

- amplifier:

$$(6) \qquad V_y = k_y u$$

- engine:

$$(7) \qquad J\frac{d\omega}{dt} = M_{dv} - M_c; \quad M_{dv} = k_{dv} V_y; \quad M_c = k_c \omega .$$

or after correspondingly substitution, the equation of the engine is:

$$(8) \qquad J\frac{d\omega}{dt} + k_c \omega = k_{dv} V_y$$

- reduction gear:

$$(9) \qquad \omega_{red} = k_{red}\omega ; \quad \frac{d\varphi}{dt} = \omega_{red} .$$

or after correspondingly substitution, the equation of the reduction gear is:

$$(10) \qquad \frac{d\varphi}{dt} = k_{red}\omega$$

On the presented equations of the separated links and on the scheme of principle one can compose the structural scheme of the system for automatically control of the antenna installations, which is shown in fig.6. The connection between The Laplace's images of the error and the desired value (input) of the system:

$$(11) \qquad \varepsilon(p) = W_{\varepsilon,\varphi}\varphi_z(p)$$

is given by transfer function , which with using the symbols: $T = \dfrac{J}{k_c}$ and $k = \dfrac{k_n k_y k_{dv} k_{red}}{k_c}$ takes the form:

$$(12) \qquad W_{\varepsilon,\varphi} = \frac{1}{k}\,\frac{T s^2 + s}{\frac{T}{k}s^2 + \frac{1}{k}s + 1}$$

The correspondingly differential equation, describes the connection (11) in the time domain is:

$$(13) \qquad \frac{T}{k}\frac{d^2\varepsilon}{dt^2} + \frac{1}{k}\frac{d\varepsilon}{dt} + \varepsilon + \frac{T}{k}\frac{d^2\varphi_n}{dt^2} + \frac{1}{k}\frac{d\varphi_n}{dt} = 0$$

Logarithmic frequency characteristics of the tower and of antenna installation.

The mathematical model of the tower, described in the upper points, is a three-dimensional, and as result of its study we obtain the revolutions in the point of the hanging of each of the antenna installations around the three axes x, y and z. In direction of these revolution we construct three electric-engine. They realise the control in direction of the rotations around the three axes. The radio and television tower is modelled by discrete model based of the finite element method with 5 868 differential equations of second order. The discrete spectre of the model consists a great number values of eigen frequencies. For the dynamical behaviour of the model an essential meaning has the first several eigen frequencies and eigen vectors. In the given case the dynamical system, which has many degree of freedom, is approximated only with three eigen frequencies and eigen vectors of oscillations in direction of each of the axes x, y and z.

The offered CS of the antenna installations is projected according to figures 4, 5 and 6. The sizing of the system for automatically control of the dynamical behaviour of the antenna installations is consisted in a suitable selection of the characteristics - the coefficient of reinforcement k and time-constant T of the used electro-engines. The criterion by determination of the parameters of the electro-engines is the minimisation of the error of revolution of the axis of the antenna installations (2).

In fig.7 are shown two frequence response characteristics. One of them is a logarithmic amplitude-frequency characteristic (LAFC) of the oscillations in direction of the axis x of the tower. The other has only negative values and corresponds of the CS of the antenna installations with electro-engine parameters k=100 and T= 0,001 s. On the summing up of

these two characteristics we obtain LAFC of the system tower 'antenna installation' CS. It has negative values in wide frequency ranges. This means, that in that ranges will effectively be suppressed the moving of the antennas provoked from outer excitations.
On the shown in fig.7 example, the average value of the LAFC of the system is smaller from 20 dB in the important frequency range. As a result of this the error from laying of the antenna will be at least 10 times smaller than the error by absence of the CS.

The satisfying of the technological limits for revolution of the corresponding cross-sections of the antenna support shows, that the sizing of the electro-engine is correctly made. In conclusion it can be mention, that the constructed CS of the antenna is able to provide a quality radio and television signal by the obtained in the upper chapters dimensions of the main support constructions of the installation.

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Table 3

quantity	node/cross section	combination	value
Max hor.moving masive part	n917 $+53^{00}$	6,7	±1,57 cm
Max hor.moving metal part	n960 $+79^{369}$	6,7	±27,06 cm
Max revolution	n960 $+79^{369}$	±6,7 E ±4,5 W	0,01906rad= $1,09^{0}$ 0,01081rad= $0,62^{0}$
Max hor. mov. W masive part	n917 $+53^{00}$	4,5	±0,35 cm
Max hor.moving from Å mas. p.	n917 $+53^{00}$	3	±1,5 cm
Max hor.moving from W met. p.	n960 $+79^{369}$	4,5	±17,9 cm
Max hor.moving from Å met. p.	n944 $+79^{369}$	3	±22,81 ñì
Max ringable force wall S11 kN/m	stretch n430 pressure n391	6 7	158 kN/m -212 kN/m
Max meridian force wall S22 kN/m	strech n540 pressure n236	6 7	300 -1890
Max moment wall ring M11 kNm/m	in n87 in 117	6 7	4,8 -3,7
Max moment wall meridian M22 kNm/m	in 237 in 141	6 7	19,5 -32,7
Max normal force	el. 12 el. 12	7 6	350,1 kN -370,4 kN
Max bend mom. in met.ring	M33 el.6,8 M22 el.3,1	6,7 6,7	1,216 kNm 7,33 kNm

Bulgarian RTV Towers
1- Ruse, 2 - Mont Snejanka, 3 - Mont Kopitoto, 4 - Belogradchik, 5 - Tolbuhin,
6- Sofia, 7 - Silistra, 8 - Kardjali, 9 - Kjustendil, 10 - Slantchev Briag,
11 - Razgrad, 12 - Tutrakan, 13 - Mont Botev

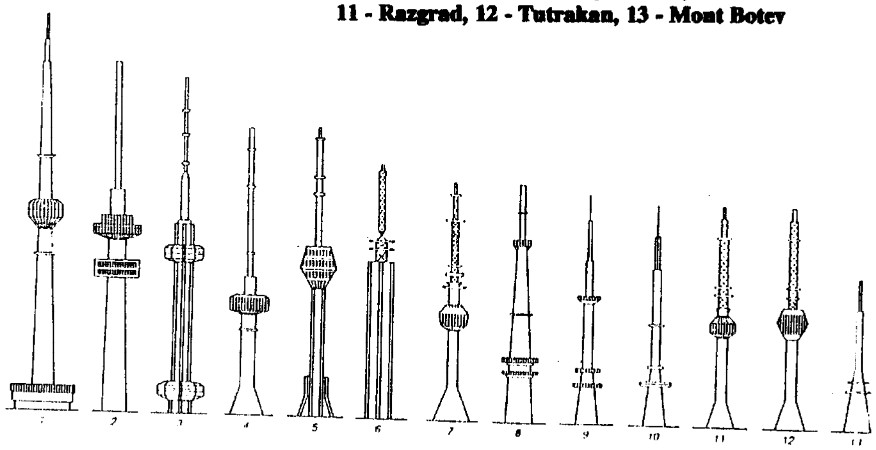

Fig.1.

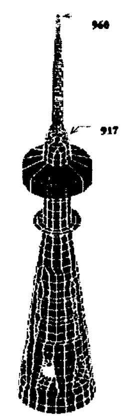

Fig.2.

Fig.3.

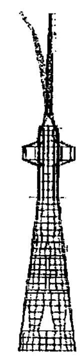

Fig.3a.

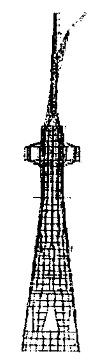

Fig.3b.

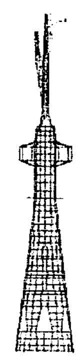

Fig.3c.

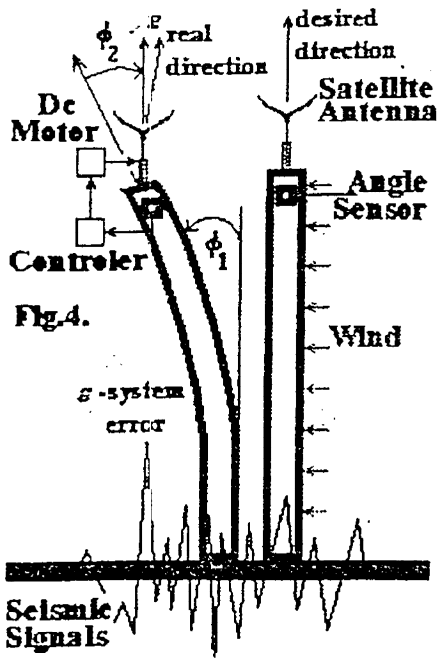

Fig.4.

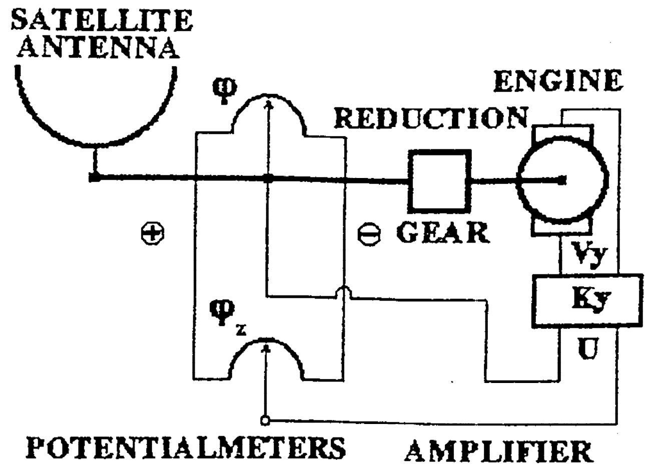

Fig.5.

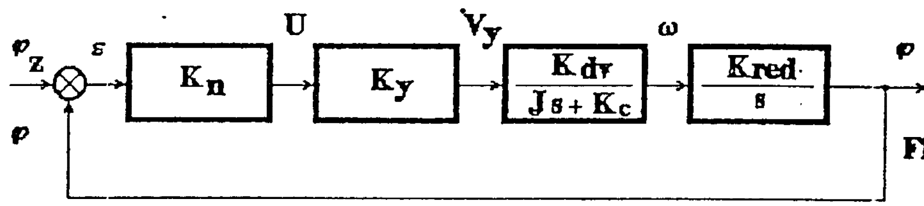

Fig.6.

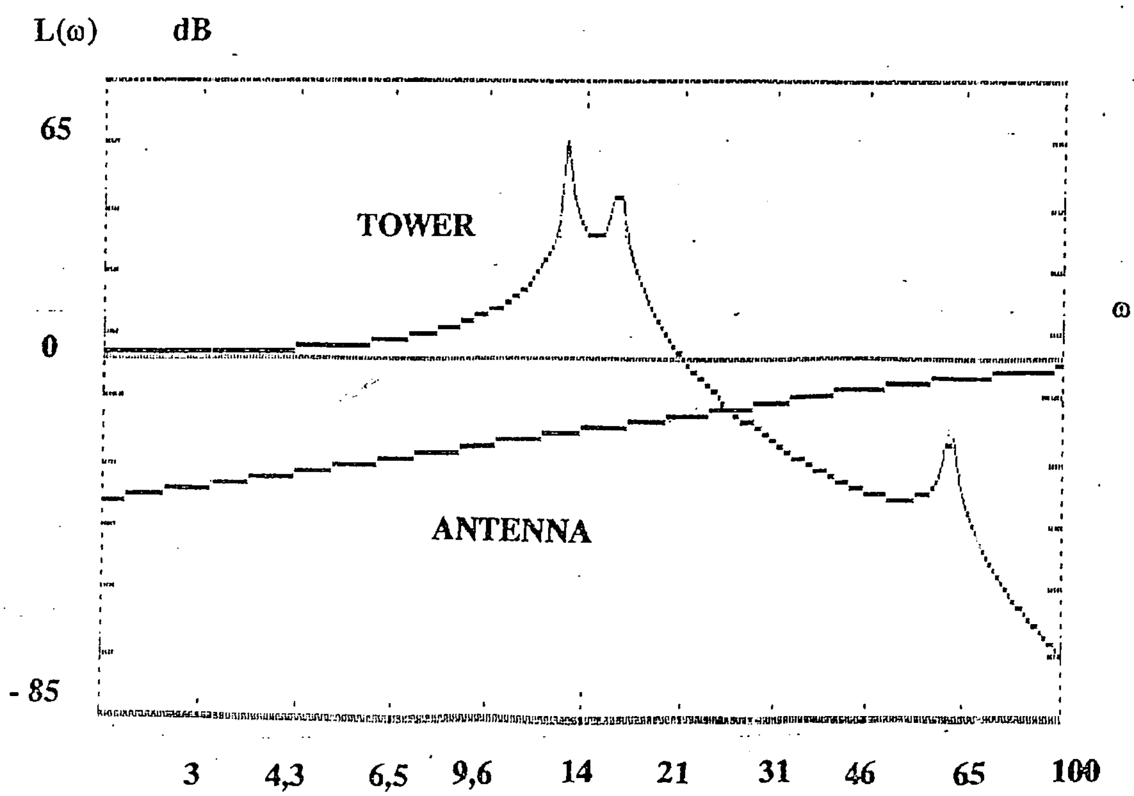

Fig.7.