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ASPECTS CONCERING LAGRANGE MODEL FOR A SYSTEM OF ORIENTATION

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ABSTRACT
In this article is presented a dynamic model for cinematic control at a structure designed for orientation solar panels (tracking control). The structure is designed by Transilvania University from Brasov and follow to put this type of structure one in Brasov, Romania, and another at Zwickau, Germany. The dynamic model use Lagrangean equations and for rejection of perturbations in position of orientation, that appear will be designed one controller of type PD and one controller of type PID in Simulink. In this article is presented only dynamic model. Controller of type PD and PID and how was calculated accord parameters Kp, Kd, Ki are presented in other article.
Keywords: Lagrange dynamic model, controller PID and PD, tracking control

1. INTRODUCTION
System of orientation solar panels is done for a column on which is put through two cinematic joints a platform with shape like a disk where are fixing solar panels (fig.1). The disk on which are fixing solar panels have two degree of freedom (fig.3). For action whole system on two degree of freedom we use an hydraulic group which action two hydraulic motor one rotary and the other linear (fig.2). The main purpose that disk have two degree of freedom is to obtain the best energetic conversion of solar energy in electrical energy. Because the system of orientation work in an environment where there are many variation like wind speed, seismic loads, temperature variations, is necessary to design a compensator for position of orientation like PD or PID controllers. System of control dispose of many digital and analogue input and output, a part of this inputs and outputs are used for different procedures. Because the speed of wind is very large owing to environment where the structure is placed, there is a procedure for reduce the surface exposed on direction of wind that bring the structure in a control position. There are also procedures that allow record all information about capacity of conversion of solar energy in electrical energy and reliable working of hydraulic system.
A global procedure is to stop the motion of structure when the pressure in hydraulic system exceed a nominal value.
The movements regarding the two degrees of freedom are rotations, one is generated by a rotary motor around one main axis situated in a plan perpendicular on the pylon axis, and the second one by a rotary cylinder, which allow the rotation of entire system around an axis perpendicular on the main axis of rotation by displacement of core bar toward cylinder. The main rotation movement is performed during one day and is between +800 and -800 regarding a vertical plan which contains the pylon.
The main movement is made in steps considering that the solar hour has 150. In order to have an incidence angle normal to the solar panels plan, a higher period of time the daily rotation takes place by adopting a displacement law which during on 150 cross the steps acceleration – steady state – deceleration. Therefore the main movement takes place considering the displacement law on periods of 150. After finishing a stage between +800 and -800 the orientation system of solar panels is taken in the start position by rotating contrary clockwise with one rotation of 1600.

Figure 1. System of orientation solar panels with all components –column, disk and joints

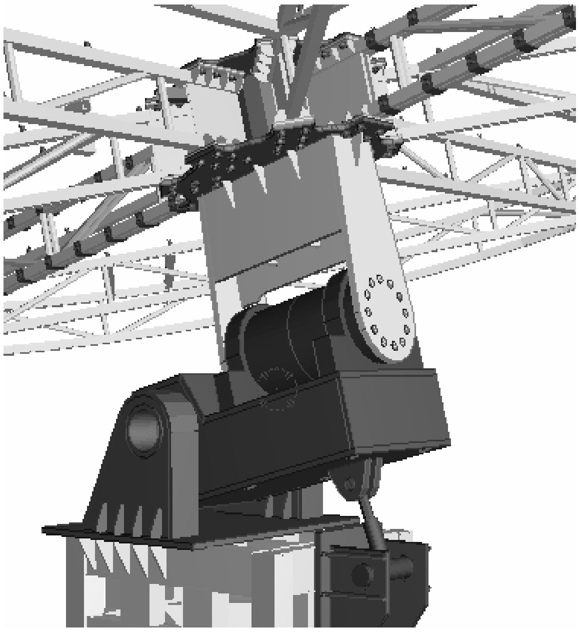

Figure 2. System of action for structure of orientation solar panels with rotary hydraulic motor and linear hydraulic motor.

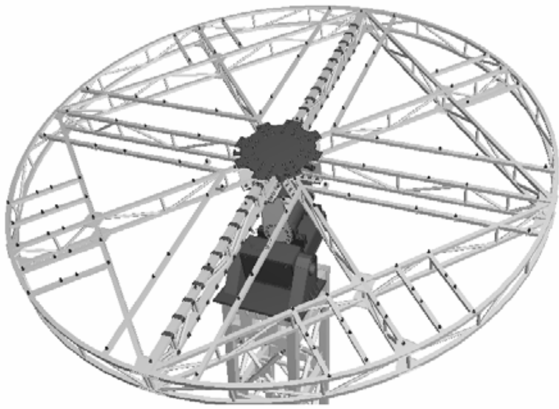

Figure 3. Disk on which is fixing solar panels for conversion solar energy in electrical energy.

The seasonal rotation movement which depends on the season takes place between 00 and 450 and it is perpendicular on the main rotation movement. Because this movement is made between big periods of time and is not necessary a high accuracy of positioning we decide that for this degree of freedom to not perform the displacement control of orientation system of solar panels. During the execution of seasonal rotation, the accelerations that appear are small due to the fact that de periods of acceleration and deceleration are done in long period of time. Clearly that the range of variation of inertia at the rotation movement around the main axis is very big because for each position between 00 and 450 in the secondary rotation couple, the disc on which are fixed the solar panels execute the main rotation movement between +800 and -800.

One of the problems that occur at the construction of this kind of structure is the transitory response of structure at acceleration and deceleration of system, due to the fact that for one complete movement are necessary, on average, 18 accelerations and decelerations of driving system during one day in the main couple of rotation. Certainly that the perturbations from positioning, introduced by inertia, can be corrected by the control system between certain limits. In order to reduce the effect of perturbations were made modal and dynamical complex analysis with the programs ETABS and SAP2000.

2. DYNAMIC MODEL FOR SYSTEM OF ORIENTATIONS SOLAR PANELS

For dynamic model in this paper author consider concentrated mass and element of system are considered rigid elements. The bodies that compose the system can be considered rigid bodies because when was designed column and disk for system of orientation solar panel was made complex modal analysis for all components of structure. Period for all components of structure is T<0,3s, in this way all components can be considered rigid bodies.

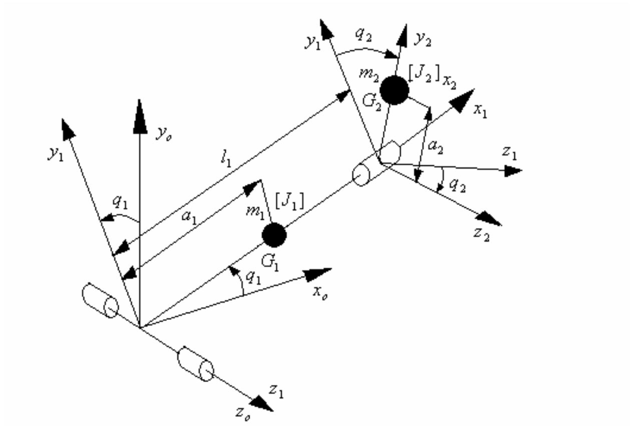

Figure 4. Dynamic model – for a system with two degree of freedom with concentrated masses and rigid elements.

Cinematic parameters-position angular speed and angular acceleration for mass m_1 and m_2 are:

-position:
$$r_1 = \begin{Bmatrix} a_1 \\ 0 \\ 0 \end{Bmatrix}_{Ox_1y_1z_1} \quad ... (1); \qquad r_2 = \begin{Bmatrix} l_1 \\ a_2 \\ 0 \end{Bmatrix}_{Ox_2y_2z_2} \quad ... (2).$$

-angular speed:
$$\omega_1 = \begin{Bmatrix} 0 \\ 0 \\ \dot{q}_1 \end{Bmatrix}_{Ox_1y_1z_1} \quad ... (3); \qquad \omega_2 = \begin{Bmatrix} \dot{q}_2 \\ 0 \\ 0 \end{Bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos q_1 & \sin q_2 \\ 0 & -\sin q_2 & \cos q_2 \end{bmatrix} \begin{Bmatrix} 0 \\ 0 \\ \dot{q}_1 \end{Bmatrix} \quad ... (4);$$

$$\omega_2 = \begin{Bmatrix} \dot{q}_2 \\ \dot{q}_1 \sin q_2 \\ \dot{q}_1 \cos q_2 \end{Bmatrix}_{Ox_2y_2z_2} \quad ... (5).$$

-angular acceleration:
$$\varepsilon_1 = \begin{Bmatrix} 0 \\ 0 \\ \ddot{q}_1 \end{Bmatrix}_{Ox_1y_1z_1} \quad ... (6); \qquad \varepsilon_2 = \frac{d}{dt}\omega_2 = \begin{Bmatrix} \ddot{q}_2 \\ \ddot{q}_1 \sin q_2 + \dot{q}_1 \dot{q}_2 \cos q_2 \\ \ddot{q}_1 \cos q_2 - \dot{q}_1 \dot{q}_2 \sin q_2 \end{Bmatrix}_{Ox_2y_2z_2} \quad ... (7).$$

Velocity for center mass of body 1:
$$v_1 = \begin{Bmatrix} 0 \\ \dot{q}_1 a_1 \\ 0 \end{Bmatrix}_{Ox_1y_1z_1} \quad ... (8).$$

Velocity for center mass of body 2: $v_2 = \tilde{\omega}_2 r_2 == \begin{Bmatrix} -\dot{q}_1 a_2 \cos q_2 \\ \dot{q}_1 l_1 \cos q_2 \\ -\dot{q}_1 l_1 \sin q_2 + \dot{q}_2 a_2 \end{Bmatrix}$ ... (9).

Kinetic energy for body with mass m_1 is: $E_1 = \frac{1}{2}\dot{q}_1^{\,2}(m_1 a_1^2 + J_{1z})$ ... (10).

Kinetic energy for body with mass m_2 is:

$$E_2 = \frac{1}{2}\dot{q}_1^{\,2}(J_{2y}\sin^2 q_2 + J_{2z}\cos^2 q_2 + m_2 a_2^{\,2}\cos^2 q_2 + m_2 l_1^{\,2}) + \\ + \frac{1}{2}\dot{q}_2^{\,2}(J_{2x} + m_2 a_2^{\,2}) - \dot{q}_1 \dot{q}_2 l_1 a_2 \sin q_2 m_2 \quad \text{... (11).}$$

Gravitational energy for body with mass m_1 is: $U_1 = m_1 g a_1 \sin q_1$ ... (12).

Gravitational energy for body with mass m_2 is: $U_2 = m_2 g(l_1 \sin q_1 + a_2 \cos q_2 \cos q_1)$ ... (13).

Generalized force that action in the joints of structure are obtained through Lagrange equations:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_k}\right) - \frac{\partial L}{\partial q_k} = Q_k \quad q = 1,2 \quad \text{... (14),}$$

where:

L langrangean for system of two bodies;

q_k generalized coordinate ;

$\dot{q}_k$ generalized velocities;

Q_k generalized force that action in the joints of structure .

Generalized force that action in first joint :

$$Q_{z1} = \ddot{q}_1(J_{1z} + J_{2y}\sin^2 q_2 + J_{2z}\cos^2 q_2 + m_1 a_1^2 + m_2(a_2^2\cos^2 q_2 + l_1^2)) - \\ - \ddot{q}_2 m_2 l_1 a_2 \sin q_2 - \dot{q}_2^{\,2} m_2 l_1 a_2 \cos q_2 + 2\dot{q}_1 \dot{q}_2 (J_{2y} - J_{2z} - m_2 a_2^2)\sin q_2 \cos q_2 \\ - m_1 g a_1 \cos q_1 - m_2 g(l_1 \cos q_1 - a_2 \sin q_1 \cos q_2); \quad \text{... (15).}$$

Generalized force that action in second joint :

$$Q_{x2} = -\ddot{q}_1 m_2 l_1 a_2^2 \sin q_2 + \ddot{q}_2 m_2 (J_{2z} + m_2 a_2^2) - \\ - \dot{q}_1^{\,2}(J_{2y} - J_{2z} - m_2 a_2^2)\sin q_2 \cos q_2 + m_2 g a_2 \cos q_1 \sin q_2. \quad \text{... (16).}$$

6. CONCLUSIONS

-Dynamic model obtained through Lagrange equations can be used to compute control parameters for structures for orientation solar panels, generalized forced being direct without compute forces of reactions from joints.

-Because the stiffness of bodies that making the structure is very large author could consider each body like a rigid body.

-Because acceleration during operation is small we can model the structure like a model with 1 degree of freedom (rotation about z axis)

7. REFERENCES

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