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DYNAMIC MODEL FOR A SYSTEM OF ORIENTATION SOLAR PANELS

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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 dynamic model uses 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 the dynamic model. The main purpose is to calculate the Kp, Kd, Ki optimal parameters using the Simulink package.

Key words: dynamic model – controller PD and PID – tracking control.

1. INTRODUCTION

The 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 solar panels (fig.2) are fixed. The disk on which the solar panels are fixed has two degrees of freedom (fig.1). For action whole system on two degree of freedom are used a hydraulic group which actions two hydraulic motors one rotary and the other linear (fig.3). The main purpose of the two degrees of freedom disk is to obtain the best energetic conversion of solar energy in electrical energy. Because the system of orientation works in an environment where there are many variations 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 disposes 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 to reduce the surface exposed on direction of wind that bring the structure in a control position. There are also procedures that allow recording 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 exceeds 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 allows 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 +80° and -80° regarding a vertical plan which contains the pylon.

The main movement is made in steps considering that the solar hour has 15°. 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 15° cross the steps acceleration – steady state – deceleration. Therefore the main movement takes place considering the displacement law on periods of 15°. After finishing a stage between +80° and -80° the orientation system of solar panels is taken in the start position by rotating counterclockwise with one rotation of 160°.

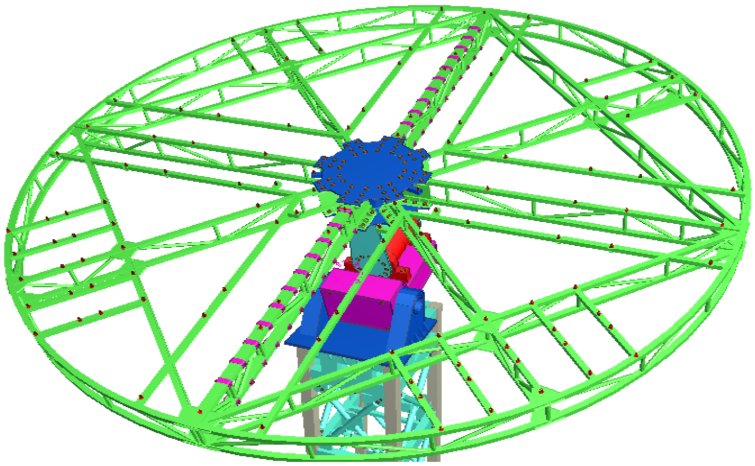

Fig.1 – Disk on which solar panels are fixed for conversion solar energy in electrical energy.

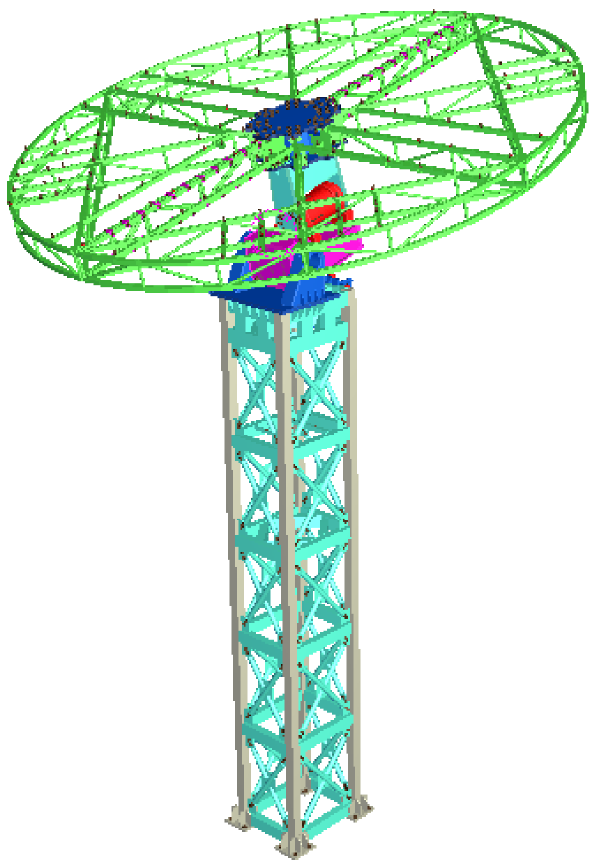

Fig. 2 – System of orientation solar panels with all components –column, disk and joints

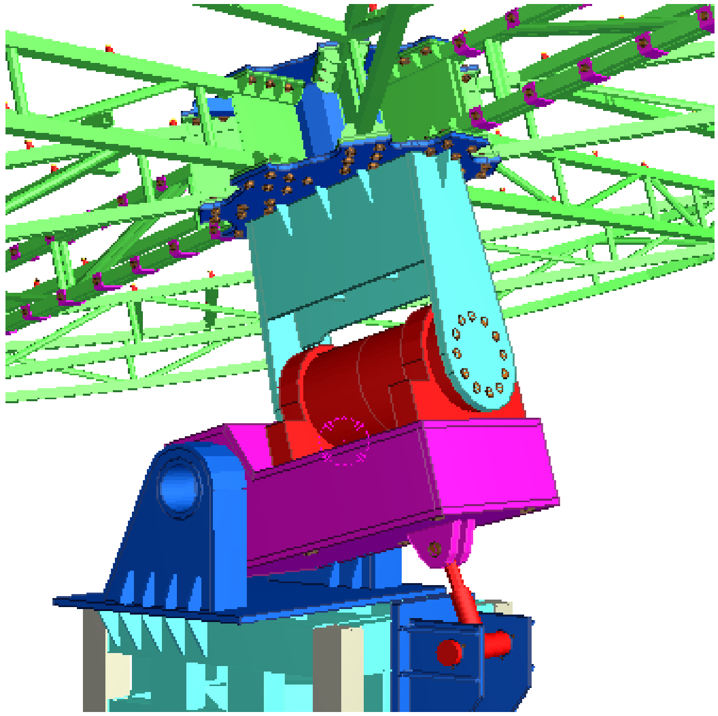

Fig.3 – System of action for structure of orientation solar panels with rotary hydraulic motor and linear hydraulic motor.

The seasonal rotation movement which depends on the season takes place between 0° and 45° 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 0° and 45° in the secondary rotation couple, the disc on which are fixed the solar panels execute the main rotation movement between +80° and -80°.

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 modal and dynamical complex analysis with the programs ETABS and SAP2000 were performed.

2. DYNAMIC MODEL FOR SYSTEM OF ORIENTATION 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 the column and disk for system of orientation solar panel was designed, complex modal analysis for all components of structure was made. Period for all components of structure is T<0,3s, in this way all components can be considered rigid bodies.

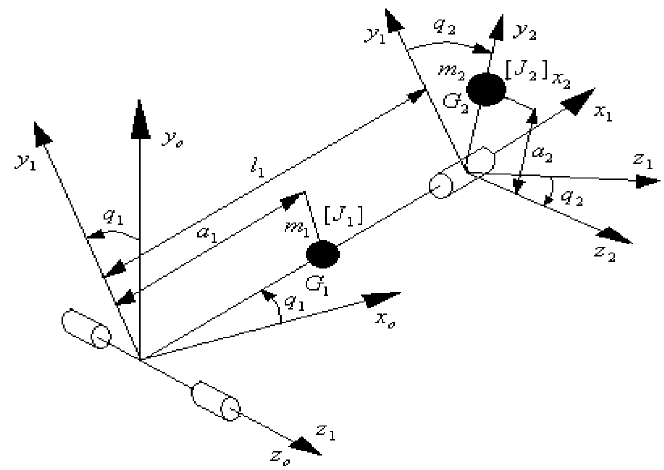

Fig.4 – Dynamic model –for a system with two degree of freedom with concentrated masses and rigid elements.

Cinematic parameters-position angular speed and angular acceleration for mass m2 are:

-position

$$r_2 = \begin{Bmatrix} l_1 \\ a_2 \\ 0 \end{Bmatrix}_{Ox_2y_2z_2} \quad (1)$$

-angular speed

$$\omega_2 = \begin{Bmatrix} \dot{q}_2 \\ 0 \\ 0 \end{Bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos q_1 & \sin q_2 \\ 0 & -\sin q_2 & \cos q_2 \end{bmatrix} \begin{Bmatrix} 0 \\ 0 \\ \dot{q}_1 \end{Bmatrix} \quad (2)$$

$$\omega_2 = \begin{Bmatrix} \dot{q}_2 \\ \dot{q}_1 \sin q_2 \\ \dot{q}_1 \cos q_2 \end{Bmatrix}_{Ox_2y_2z_2} \quad (3)$$

-angular acceleration

$$\varepsilon_2 = \frac{d}{dt}\omega_2 = \begin{Bmatrix} \ddot{q}_2 \\ \ddot{q}_1 \sin q_2 + \dot{q}_1 \dot{q}_2 \cos q_2 \\ \ddot{q}_1 \cos q_2 - \dot{q}_1 \dot{q}_2 \sin q_2 \end{Bmatrix}_{Ox_2y_2z_2} \quad (4)$$

Cinematic parameters for mass m1 are:

-position

$$r_1 = \begin{Bmatrix} a_1 \\ 0 \\ 0 \end{Bmatrix}_{Ox_1y_1z_1} \quad (5)$$

-angular speed

$$\omega_1 = \begin{Bmatrix} 0 \\ 0 \\ \dot{q}_1 \end{Bmatrix}_{Ox_1y_1z_1} \quad (6)$$

-angular acceleration

$$\varepsilon_1 = \begin{Bmatrix} 0 \\ 0 \\ \ddot{q}_1 \end{Bmatrix}_{Ox_1y_1z_1} \quad (7)$$

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:

$$v_2 = \tilde{\omega}_2 r_2 == \begin{Bmatrix} -\dot{q}_1 a_2 \cos q_2 \\ \dot{q}_1 l_1 \cos q_2 \\ -\dot{q}_1 l_1 \sin q_2 + \dot{q}_2 a_2 \end{Bmatrix} \quad (9)$$

Kinetic energy for body with mass m1 is:

$$E_1 = \frac{1}{2}\dot{q}_1^{\,2}(m_1 a_1^2 + J_{1z}); \quad (10)$$

Kinetic energy for body with mass m2 is:

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

Gravitational energy for body with mass m1 is:

$$U_1 = m_1 g a_1 \sin q_1 \quad (12)$$

Gravitational energy for body with mass m2 is:

$$U_2 = m_2 g(l_1 \sin q_1 + a_2 \cos q_2 \cos q_1) \quad (13)$$

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

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

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 :

$$\begin{aligned} Q_{z1} &= \ddot{q}_1(J_{1z}+J_{2y}\sin^2 q_2+J_{2z}\cos^2 q_2+ \\ &+m_1a_1^2+m_2(a_2^2\cos^2 q_2+l_1^2))- \\ &-\ddot{q}_2\, m_2l_1a_2\sin q_2-\dot{q}_2^{\,2}\, m_2l_1a_2\cos q_2+ \\ &+2\dot{q}_1\dot{q}_2(J_{2y}-J_{2z}-m_2a_2^2)\sin q_2\cos q_2 \\ &-m_1ga_1\cos q_1-m_2g(l_1\cos q_1-a_2\sin q_1\cos q_2); \end{aligned} \tag{15}$$

Generalized force that action in second joint :

$$\begin{aligned} Q_{x2} &= -\ddot{q}_1\, m_2l_1a_2^2\sin q_2+\ddot{q}_2\, m_2(J_{2z}+m_2a_2^2)- \\ &-\dot{q}_1^{\,2}\,(J_{2y}-J_{2z}-m_2a_2^2)\sin q_2\cos q_2+ \\ &+m_2ga_2\cos q_1\sin q_2. \end{aligned} \tag{16}$$

3. 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 the 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).

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