ANALELE UNIVERSITĂŢII
"EFTIMIE MURGU" REŞIŢA
ANUL XXI, NR. 2, 2014, ISSN 1453 - 7397

Gheorghe Manolea, Sergiu Ivanov, Laurenţiu Alboteanu, Constantin Şulea, Ștefan-Marian Nicolae

Design and Control of the Electric Drive of the Anti-Hail Launching System

In the present, the Romanian anti-hail launchers are manually operated. This means that the positioning of the launcher on the two directions (azimuth and elevation) are adjusted based on the commands, by the human operator. The paper describes the design, implementation and experimental results of the electric drives of the two axes by using permanent magnets synchronous motors (PMSM) supplied by smart drives. The solution offers the possibility of automation and integration of the anti-hail launchers within intelligent systems.

Keywords: anti-hail, design, PMSM drive

Introduction

There are well known the devastating effects of the hail, both for the agriculture, but also for homes, cars and even for people when the dimensions are quite important.

During the time more anti-hail systems were developed and used around the world. For example in France, for defending the vine fields, about 650 silver-iodide generators located on the ground are used. The generators are always ready to be activated based on the warnings issued by Meteo-France [1], [2].

The advantages of the system are related to low maintenance costs, low qualification operators, no disturbances of the plains traffic. The drawbacks are related to the low efficiency and high consumption of the seeding material.

Other two methods for anti-hail protection consist in seeding the hail clouds by rockets launched from the ground or by plains respectively [3].

The seeding by plains has limitations face to the seeding performed by rockets launched from the ground. Consequently, the most used anti-hail system consists in rocket launchers. There is not a standard concerning the size of the rockets or of the launchers. Each interested country developed its own system.

The Romanian anti-hail system

In Romania there are two regions protected by anti-hail systems: one for Prahova and Buzău countries and another for Iaşi and Vaslui countries.

Basically, the anti-hail system consists in:

- meteorological radars system (Fig. 1);
- command center;
- 6 to 12 lounching points (Fig. 2);
- logistic and communication system.

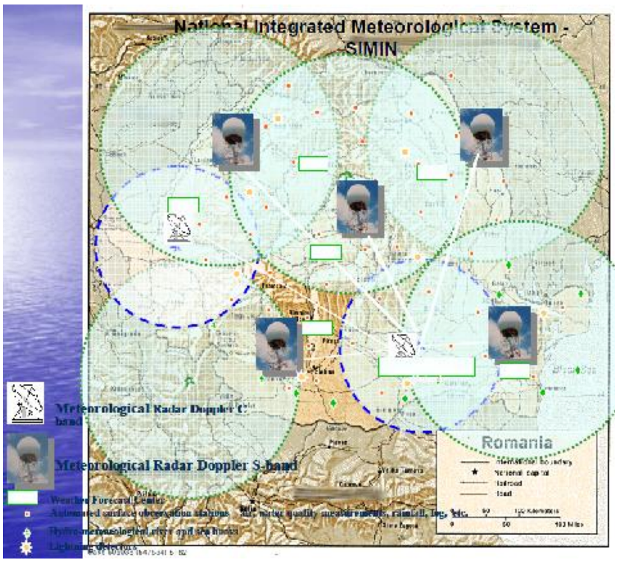

Figure 1. The meteorological radar system in Romania

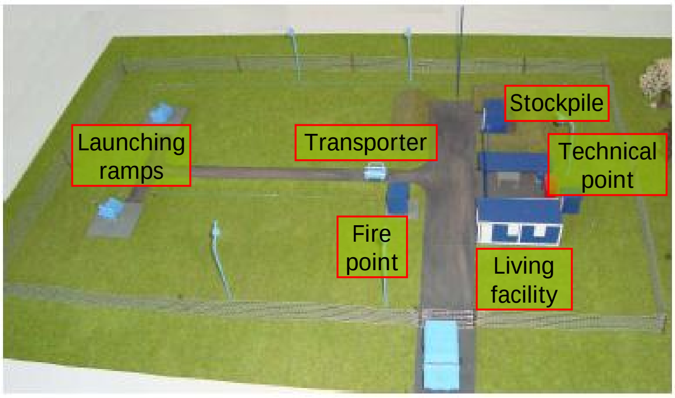

Figure 2. Launching point

The launching ramps are heavy metallic structures (more than 250 kg), Fig. 3, capable to sustain simultaneously up to 8 rockets, each on its own beam.

Figure 3. Mechanical structure of the launching ramp

Few of the mechanical characteristics and requirements are listed below:

- Azimuth orientation angle: 0 - 360° by 5° increments;
- Elevation orientation angle: 20° - 85° by 5° increments;
- Forbidden sectors can be set;
- Precision of the drive for azimuth angle: ±1,5°;
- Precision of the drive for elevation angle: ±1,5°;
- Minimum speed for azimuth orientation: 20°/s;
- Minimum speed for elevation orientation: 10°/s;
- Maximum time for position setup: 100 ms;
- Time for position setup after command issue: 20-30 s;
- Deep-seated on the commanded position for azimuth and elevation.

The position (azimuth and elevation) ordered by the command center based on the information issued by meteorological radars, must be set by the launching points operators in less than 10 minutes. It must be underlined that for the actual situation, this operation must be performed manually at any time, during storm conditions.

For this reason, but also for increasing the security of the operation and for the integration of the anti-hail launchers within intelligent systems, the electric drive of the two orientation axes was studied and finally implemented.

Bellow the results will be presented.

The design of the electric drives

The design of the two electric drives followed the classical approach, but based on experimental determinations of the static torques by using dynamometric devices [5]. The results were compared with the ones resulted from theoretical considerations. Additional components were considered for taking into account the wind pressure.

In what concerns the azimuth orientation, experimental tests gave a static torque of $T_{sA} = 7.5 N \cdot m$.

It result the static power neccessary for rotating the ramp on the azimuth direction

$$P_{sA} = T_{sA} \cdot \mu_A , \tag{1}$$

where μ_A is the maximum angular velocity imposed for this movement

$$\mu_A = 20^\circ / s \cdot \frac{\text{®}}{180^\circ} = 0.35 rad / s . \tag{2}$$

It results

$$P_{sA} = T_{sA} \cdot \mu_A = 7.5 \cdot 0.35 = 2.625 W , \tag{3}$$

The dynamic torque was also considered. On the azimuth direction, the whole superior part of the ramp must be accelerated, including the maximum load of 8 rockets. Due to the complex mechanical structure (Fig. 5), the total inertia can only be evaluated:

$$J_A = m_A \cdot r_A^2 = 250 \cdot (0.52)^2 = 67.6 kg \cdot m^2 , \tag{4}$$

where $m_A = 250 kg$ is the total mass of the loaded superior part and $r_A = 0.52 m$ is the average radius of the superior part of the ramp.

The angular acceleration on the azimuth direction is expressed as finite difference of the maximum angular velocity and the maximum time for position setup, 100 ms. It results the necessary dynamic torque on the azimuth direction

$$T_{dA} = J_A \cdot \frac{\mu_A}{0.1} = 67.6 \cdot \frac{0.35}{0.1} = 236.6 N \cdot m . \tag{5}$$

Finally, the total necessary torque to be developed by the motor which will drive the superior part of the ramp is

$$T_A = T_{sA} + T_{dA} = 7.5 + 236.6 = 244.1 N \cdot m . \tag{6}$$

It results the necessary power

$$P_A = T_A \cdot \mu_A = 244.1 \cdot 0.35 = 85.44 W . \tag{7}$$

Considering the additional looses corresponding to the mechanical transmission, but also the possible wind influence, a PMSM BSM 55-0070-3 from Parker was chosen. The main characteristics of this motor are:

- Rated power P_N = 188 W;

- Rated torque T_N = 0.45 Nm;
- Rated speed n_N = 4000 rot/min.

As transmission for the azimuth axis, a worm reducer was chosen with transmission ratio

$$i_A = 100\,, \tag{8}$$

which will also ensure the deep-seated on the commanded position for azimuth.

In what concerns the elevation orientation, experimental tests gave a static torque of $T_{sE} = 83 N \cdot m$.

It result the static power necessary for rotating the ramp on the elevation direction

$$P_{sE} = T_{sE} \cdot \omega_E\,, \tag{9}$$

where ω_E is the maximum angular velocity imposed for this movement

$$\omega_E = 10^\circ / s \cdot \frac{\pi}{180^\circ} = 0.175 rad / s\,. \tag{10}$$

It results

$$P_{sE} = T_{se} \cdot \omega_E = 83 \cdot 0.175 = 14.53 W\,, \tag{11}$$

The dynamic torque was also considered. On the elevation direction, the support of the 8 loaded beams must be accelerated. Due to the complex mechanical structure (Fig. 5), the total inertia can only be evaluated:

$$J_E = m_E \cdot r_E^2 = 150 \cdot \left(0.77\right)^2 = 88.94 kg \cdot m^2\,, \tag{12}$$

where $m_E = 150 kg$ is the total mass of the loaded beams and $r_E = 0.77 m$ is the average radius of the beams around the rotating point.

The angular acceleration on the elevation direction is expressed as finite difference of the maximum angular velocity and the maximum time for position setup, 100 ms. It results the necessary dynamic torque on the elevation direction

$$T_{dE} = J_E \cdot \frac{\omega_E}{0.1} = 88.94 \cdot \frac{0.175}{0.1} = 156 N \cdot m\,. \tag{13}$$

Finally, the total necessary torque to be developed by the motor which will drive the elevation axis is

$$T_E = T_{sE} + T_{dE} = 83 + 156 = 239 N \cdot m\,. \tag{14}$$

It results the necessary power

$$P_E = T_E \cdot \omega_E = 239 \cdot 0.175 = 41.825 W\,. \tag{15}$$

Considering the additional looses corresponding to the mechanical transmission, but also the possible wind influence, a PMSM 055E2B300BACRA063110 from Control Techniques was chosen. The main characteristics of this motor are:

- Rated power P_N = 330 W;
- Rated torque T_N = 1.05 Nm;

- Rated speed n_N = 3000 rot/min.

As transmission for the elevation axis, a worm reducer was chosen with transmission ratio

$$i_E = 500\,, \tag{16}$$

resulted from two cascaded worm reducers (i_1=10, i_2=50). This transmission will also ensure the deep-seated on the commanded position for elevation.

The control of the drives and implementation

The command of the two motors is performed based on the preset values of the two directions, received from the Command center. Locally, each motor is supplied by an intelligent driver from Control Techniques [4], [5], Fig. 4.

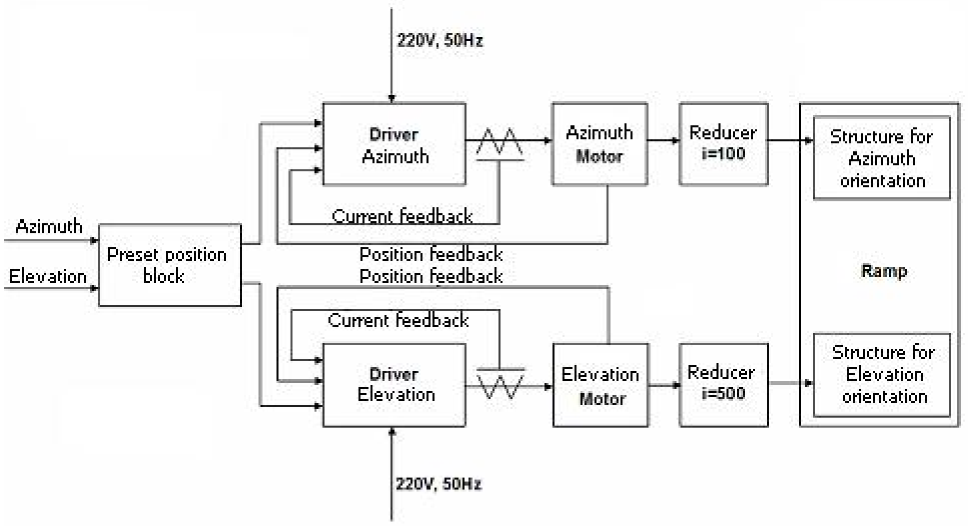

Figure 4. Block diagram of the positioning system.

Locally, each driver controls the associated PMSM by using vector control. It will be detailed here the whole procedure of programming the intelligent drives, but it must be highlighted only the large versatility and availability of them.

In Fig. 5 and 6 images of the experimental assembly are presented. We note the compactness of the chosen solution.

We must underline here that the solution was agreed by the industrial partner which produces the mechanical structure and thanks to the very fine positioning performances (better than 0.003°, compared with the technical specification of ±1,5°), it is possible that the solution would be applied to other devices too.

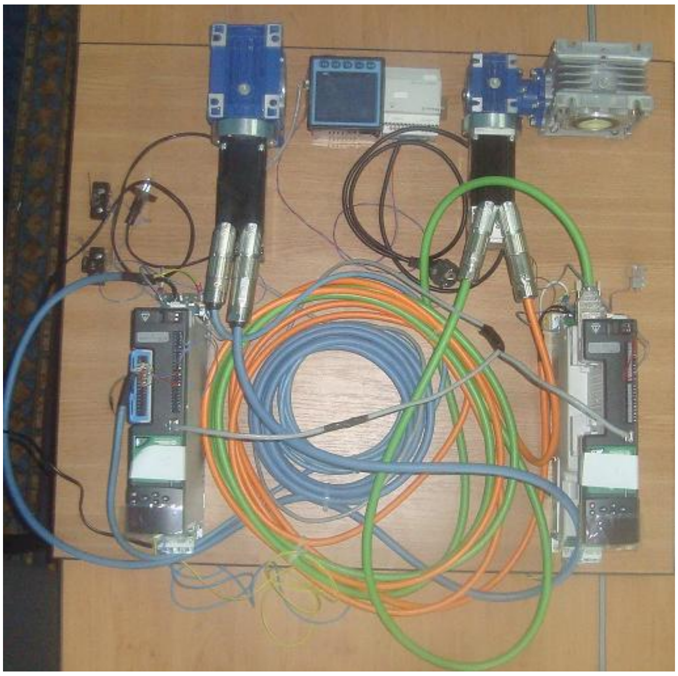

Figure 5. Laboratory setup of the drives.

Figure 6. Elevation drive mounted on the ramp.

Conclusions

The paper presented the approach and the results concerning the implementation of two modern electric drives on an equipment which requires precision positioning and high safety in operation.

The prototype of the drives proved the viability and versatility of the chosen solution.

Acknowledgement

Authors whish to thank the UE for the Romania-Bulgaria Cross-Border Cooperation Program 2007-2013 and their partners in the project “Joint Risk Monitoring during Emergencies in the Danube Area Border”, in the frame of which their study has been performed.

References

[1] ***** http://www.anelfa.asso.fr/-Prevention-.html.

[2] ***** http://www.anelfa.asso.fr/-Efficacite-.html.

[3] ***** http://www.cloud-seeding.com/.

[4] ***** Joint Risk Monitoring during Emergencies in the Danube Area Border. MIS-ETC Code: 166, Application number 2S-2.2-1.

[5] ***** Comanda şi controlul sistemului de acţionare pentru poziţionarea automată a rampei de lansare a rachetelor antigrindină, Internal Report RI1-48/A3.2.7.

Addresses:

- Prof. Dr. Eng. Gheorghe Manolea, University of Craiova, A.I. Cuza Str., nr. 13, 200585, Craiova, ghmanolea@gmail.com
- Prof. Dr. Eng. Sergiu Ivanov, University of Craiova, A.I. Cuza Str., nr. 13, 200585, Craiova, sergiu.ivanov@ie.ucv.ro
- Lect. Dr. Eng. Laurenţiu Alboteanu, University of Craiova, A.I. Cuza Str., nr. 13, 200585, Craiova, lalboteanu@em.ucv.ro
- Assist. Dr. Eng. Constantin Şulea, University of Craiova, A.I. Cuza Str., nr. 13, 200585, Craiova, constantin.sulea@gmail.com
- Assist. Eng. Ștefan-Marian Nicolae, University of Craiova, A.I. Cuza Str., nr. 13, 200585, Craiova, nmarianstefan@yahoo.com