Contributions to the Development of Complementary Equipment for the Romanian Anti-Hail System

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Abstract - **The method used in Romania for combating hail is the sowing of the clouds method, with missiles launched from the ground. This paper presents contributions of the University of Craiova, Center for Innovation and Technology Transfer in the development Hail Suppression System. The primary contribution was the complementary equipment that was necessary for developing the anti-hail system in Romania. Two of the systems that contain the anti-hail complementary equipment are showcased: the photovoltaic panels power supply system and the automatic positioning system for missiles launch ramp, respectively. The configuration of the accomplished photovoltaic system provides the power for the 12V, 24V, and 48V DC consumers and the 220V AC consumers as well. Likewise, this system can also function independently, interconnected with other energy sources (such as wind turbines, diesel generators, etc.), or synchronized with the national power grid. An energy management system was created, to secure the energy required to launch the anti-hail missiles (high priority consumers). The energy management system controls and monitors the energy flow from the photovoltaic panels to the consumers, using a hierarchy of consumers algorithm. The automatic positioning system for anti-hail missiles launch ramps contains intelligent motor drives and a touchscreen human interface. Credited to the research work and the accomplished complementary equipment, the University of Craiova - Innovation and Technology Transfer Centre became part of "General designer of the anti-hail Romanian system".**

Cuvinte cheie: *antigrindină, rachete de suprimare, panouri fotovoltaice, managementul energiei, rampe de lansare rachete, sisteme de pozitionare.*

Keywords: *anti-hail, suppression missiles, photovoltaic (PV) panel, energy management, missiles launch ramp, positioning system.*

I. INTRODUCTION

As a result of the research on anti-hailstorm systems operating in several countries, it has been found that from the price/efficiency ratio, the most widely used method uses rockets for seeding cloud with condensation substances [1]. This technique of combating hail storms is also used in Romania.

From an operational point of view, the anti-hail system in Romania includes Zonal Command Centers and Local Units for launching anti-hail missiles.

The research of the University of Craiova - the Center for Innovation and Technology Transfer (UCV-CITT) in the field of anti-hail systems began in 1998 and has been carried out in the following directions:

- the power supply of anti-hail local units from renewable sources;
- the automatic positioning system for missiles launch ramps;
- the system for monitoring the specific parameters of local anti-hail units;
- the integrated informatics system specific to local anti-hail units.

This paper presents the results obtained regarding the power supply from renewable sources, respectively the automatic positioning of the launch ramps.

II. POWER SUPPLY OF A LOCAL ANTI-HAIL UNIT FROM PHOTOVOLTAIC PANELS

A. *Structure of a local anti-hail Unit*

Each Command Center is linked to several Local Missile Launch Units, typically located in areas isolated from the power distribution network. Local launch units are located in the plain near the areas to be protected. At the same time, they should not be located near inhabited areas to avoid endangering the public safety. Launching units, as well as logistic depots, are subject to stringent legislation regarding the minimum distance from inhabited areas, ensuring the protection of the public and security of the equipment.

Fig. 1. Structure of local anti-hail unit: 1- suppression missiles launch ramps; 2- command point for missiles launch; 3- box housing; 4- missiles transport trolley; 5- technical point; 6- missiles depot.

Fig. 2. View of a missile launch site

B. Designing the power supply system from photovoltaic panels

For the power supply of a local anti-hail unit at the national network parameters, we designed a system using the primary energy obtained from photovoltaic panels.

The block diagram of the proposed system is shown in Figure3.

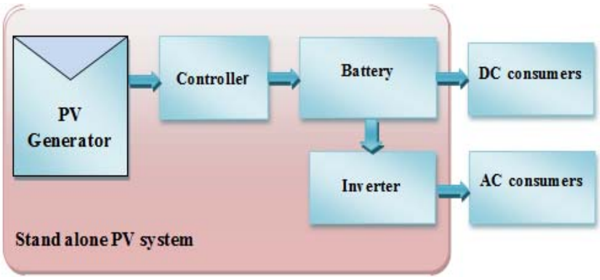


Fig. 3. Structure of the photovoltaic power supply system.

Fig. 4. Batteries of a missile launch site

Starting from the general structure of power supply to consumers in the local anti-hail units (Fig. 3), categories of consumers have been identified, and the needed elec-tricity for one day was calculated (Table I).

TABLE I. THE CHARACTERISTICS OF THE ELECTRICAL EQUIPMENT OF A LOCAL ANTI-HAIL UNIT

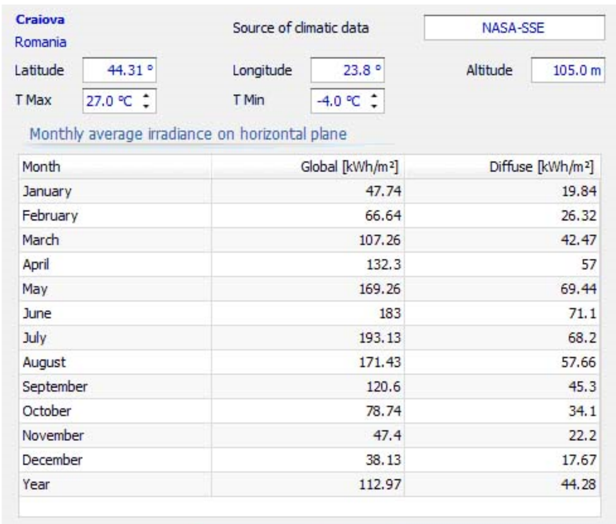
Consumers	Nominal power, [W]	Lifetime, [h/day]	Electricity needed, [Wh/day]
Radio station	30	1	30
Warhead missile launchers	12x1,2	0,3	4,36
Servodrive of ramp orientation	2x60	0,5	60
Development system with microcontroller	20	1	20
Lighting - saving bulb - fluorescent bulb	 11 2x13	 2 8	 22 208
Electric cooker	2100	1	2100
Microwave oven	1500	0,2	300
Refrigerator	200	5	1000
TV	150	2	300
Satellite antenna	30	2	60
Radio	20	6	120
Notebook	100	4	400
Total electricity needed [Wh/day]			**4625**

For the sizing of the photovoltaic system, the following steps were taken:

- evaluation of the solar radiation in the area;
- dimensions and choice of photovoltaic panels;
- evaluation of the battery capacity;
- dimensions and choice of components (regulator, inverter, protection).

Using the dedicated software BlueSol, the monthly average of the solar radiation based on NASA-SSE database was obtained (Fig. 5 and Fig. 6).

Considering the monthly average daily irradiation and the number of days which make up the twelve months of the year, the value of the annual global irradiation on a horizontal surface for the location of Craiova can be determined. This amount is equal to 3.71 [kWh/m²].



Craiova
Romania

Source of climatic data: NASA-SSE

Latitude 44.31 ° | Longitude 23.8 ° | Altitude 105.0 m

T Max 27.0 °C | T Min -4.0 °C

Monthly average irradiance on horizontal plane

Month	Global [kWh/m²]	Diffuse [kWh/m²]
January	47.74	19.84
February	66.64	26.32
March	107.26	42.47
April	132.3	57
May	169.26	69.44
June	183	71.1
July	193.13	68.2
August	171.43	57.66
September	120.6	45.3
October	78.74	34.1
November	47.4	22.2
December	38.13	17.67
Year	112.97	44.28

Fig. 5. Monthly average irradiance of Craiova location

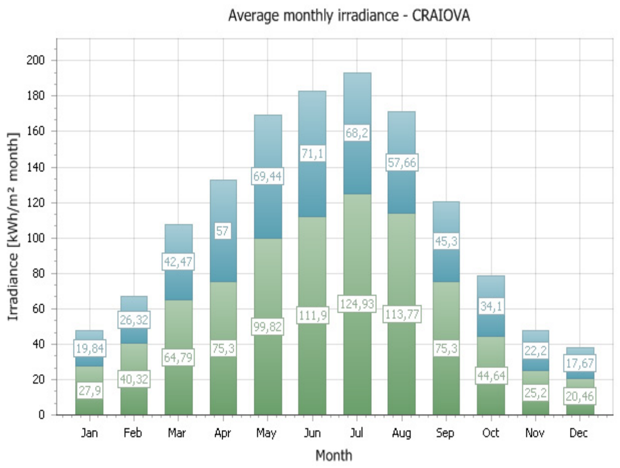


Fig. 6. Chart of monthly average irradiance of Craiova location

The graphs show that the annual average of global solar irradiation is 112.97 [kWh/m^2] and the monthly average is between 38.13 [kWh/m^2] and 193.13 [kWh/m^2].

Also, for a comparison of monthly average irradiation obtained with BlueSol software (Fig. 6), in Fig. 7 is presented the chart of the average monthly solar radiation obtained from the measurements.

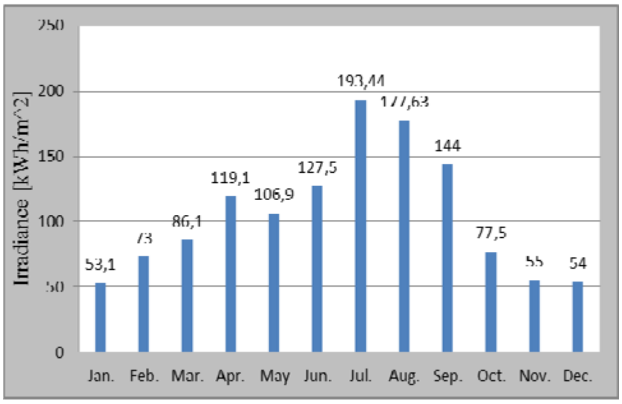


Fig. 7. Chart of monthly average irradiance measured on PV panel plane for Craiova location

Measurements were made on the solar potential at Craiova and photovoltaic modules TSM type were chosen, with maximum power Pmax = 195 [W], the current at maximum power Imp = 5.31 [A], and the voltage at the maximum power Vmp= 36.7 [V].

We chose SB 12/185 batteries with rated voltage 12 [V] and the nominal capacity of 185 [Ah] (Fig. 8).

a) b) c)

Fig. 8. The components of the photovoltaic system: a) photovoltaic panels; b) controller and inverter; c) battery bank.

DC consumers are supplied directly from one or both of the two batteries and 220 V, 50 Hz AC consumers have the power supplied through a 3kVA inverter (type VFX3024E), with 3 kVA nominal continuous output power at 25°C, 24 V DC nominal input voltage, and 230 V / 50 Hz AC output voltage/frequency (Fig. 8).

The photovoltaic system is made in a compact construction and incorporates the inverter, the regulator, the monitoring and control system as well as the protective elements (Fig.8). This system connects directly to the photovoltaic panels, batteries, and consumers. It also allows for interactive operation with the power grid, if any.

Using the BlueSol software, based on the available solar irradiation values at the Craiova location and the catalog data of the PV system equipment, the electric energy output of the analyzed system was estimated (Figure 9).

Summing up the monthly energy output results in an annual PV system energy output of about 4020 [kWh].

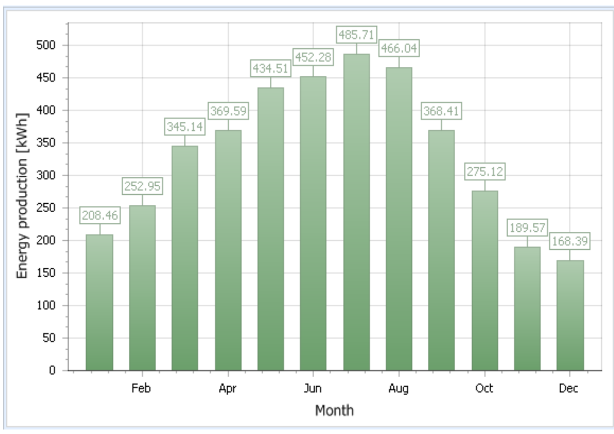


Fig. 9. Monthly energy production of PV system expected during the year

III. Energy Management Of Photovoltaic System

For the management of power flow from photovoltaic panels, energy consumption and the reserve of energy stored in batteries to ensure in all circumstances, the energy required to launch the anti-hail missiles, the algorithm of the hierarchy of consumers was elaborated and a system for power flow control was designed (Fig. 10) [2], [3].

The monitoring of energy flow from PV panels was made by a development system based on a numerical type structure; Atmega128 microcontroller from the AVR family, produced by ATMEL Company, built in SMD technology.

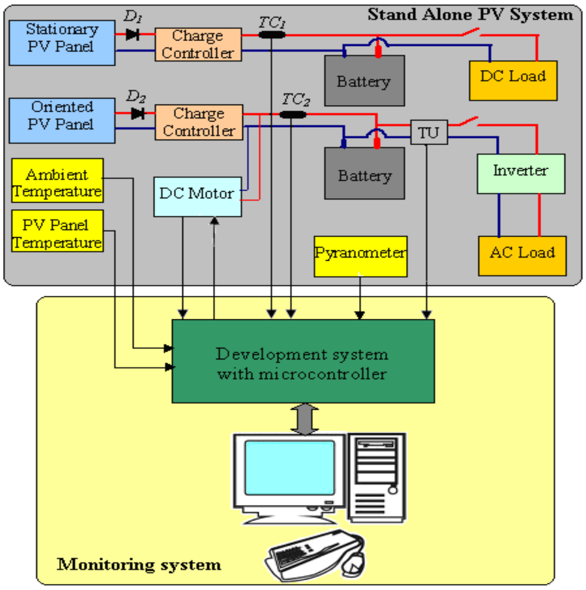


Fig. 10. Block diagram of power flow monitoring: TC1...TC3 – current transducers; TU – voltage transducer; D1, D2- diodes.

From the design stage, the development system with the microcontroller was structured on three separate modules, for better flexibility and easier troubleshooting [4], [5], [6]. The modules are structured as follows (Fig. 11):

- CPU module;
- Process interface module;
- Power supply module.

For supplying the development system DC-DC sources with galvanic separation were used, which are fed by the batteries and provide the 5VDC and 12 VDC output voltages.

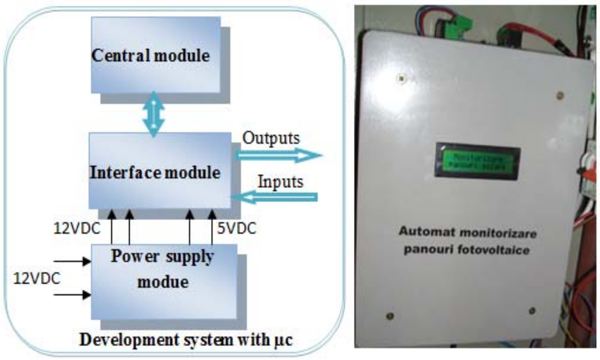


Fig.11. Development system for power flow monitoring: a) block diagram; b) achieved prototype.

The interface module has the following tasks:

- control connection/disconnection of consumers on types of priorities;
- data acquisition from sensors and transducers. For a greater flexibility in test achievements, the solution of storage data acquisition on the PC [4], [7], [8] was chosen. Also, the switching commands are summarized at the PC level.

For ATMEGA128 microcontroller programming, the software AVR3 Studio was used. The program was designed in "C", knowing that the ATMEGA family has been optimized for the use of high-level languages. The language chosen for the development of PC's software is Visual Basic.

The validation of the physical model of the automated monitoring system achieved is given by the experimental results obtained on-line from this process (Fig. 12).

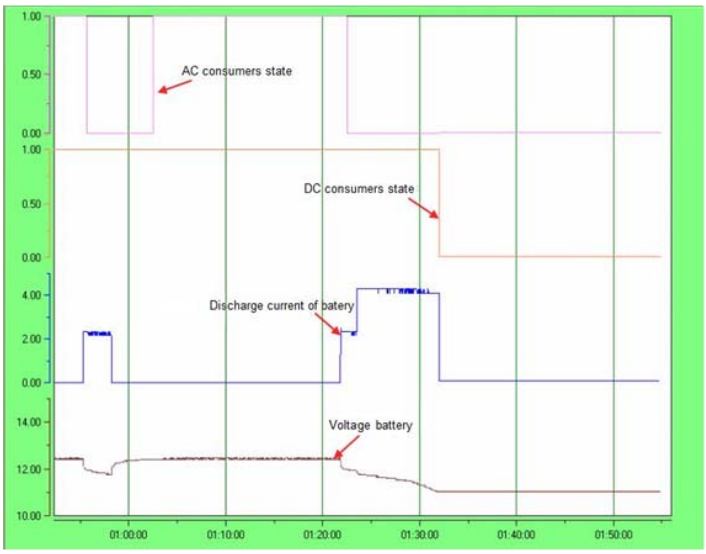


Fig. 12. Online acquisition signals provide from PV system.

The facilities provided by the Visual Basic program and increased flexibility of the software modules, Iocomp products have enabled a computer program capable of ensuring the control of photovoltaic panel, energy movement monitoring, and storage of acquired data.

Four channels are available, which can present the currents through the panels, the current absorbed from the battery, the voltage at the battery terminals, the solar radiation, the ambient temperature, the temperature of a photovoltaic panel, the panel's current position (in number of parties to the origin), and the consumers state of AC and DC current.

The physical model allows disconnection of the two categories of consumers: Category 1 (DC consumers) and Category 2 (AC consumers). Due to the operation protocol required, Category 0 consumers (telephone and anti-hail rocket) must be allowed to be continuously connected to their source of energy.

If the battery voltage rises above the threshold of 12.5V, the AC consumers are connected. They are disconnected below 12V. DC consumers are connected until the voltage drops below 11V.

IV. Automatic Positioning Of Launch Pad

The launching pad of anti-hail missiles (Fig. 13) is intended to ensure the launching of RAG-96 or RAG-96S type missiles. Its positioning is done manually after two axes: azimuth and elevation.

In the cross-border project MIS-ETC Code: 166. Application number: 2S-2.2-1, "Integrated system for monitoring and control of the equipment located in a local launch unit for anti-hail missiles"[9] it was studied and proposed a solution to increase the technical performance of this mechanical construction through automatic positioning [10].

The mechanical structure of launch pad for anti-hail missiles is shown in Figure 13.

Fig.13. Mechanical structure of a launch pad: 1- launch girder; 2- shelf; 3- distribution block; 4- azimuth/elevation cradle.

The principle of the ramp positioning is derived from the block schematic diagram of the ramp positioning system (fig. 14). To prescribe a position, it was proposed to use a touchscreen, which allows the manual setting of the position and sending the command to the drivers for positioner in the direction of azimuth and elevation, respectively. Each Driver is powered with a 48 DC voltage and outputs a 3x220 AC voltage to supply the synchronous motors with permanent magnets for azimuth and elevation positioning directions. The connection between the motor and the mechanical structure is achieved by means of a worm gear and a worm-wheel transmission which ensures one-way movement and mechanical locking of the ramp to the end position.

Verification of the operation of the positioning system was done by means of an experimental platform (Fig. 15), which will also be used for the training of ramp servicing personnel.

The system provides azimuth positioning between 0 and 360° and positioning on the elevation axis between 20° and 85° (multiple of 5°).

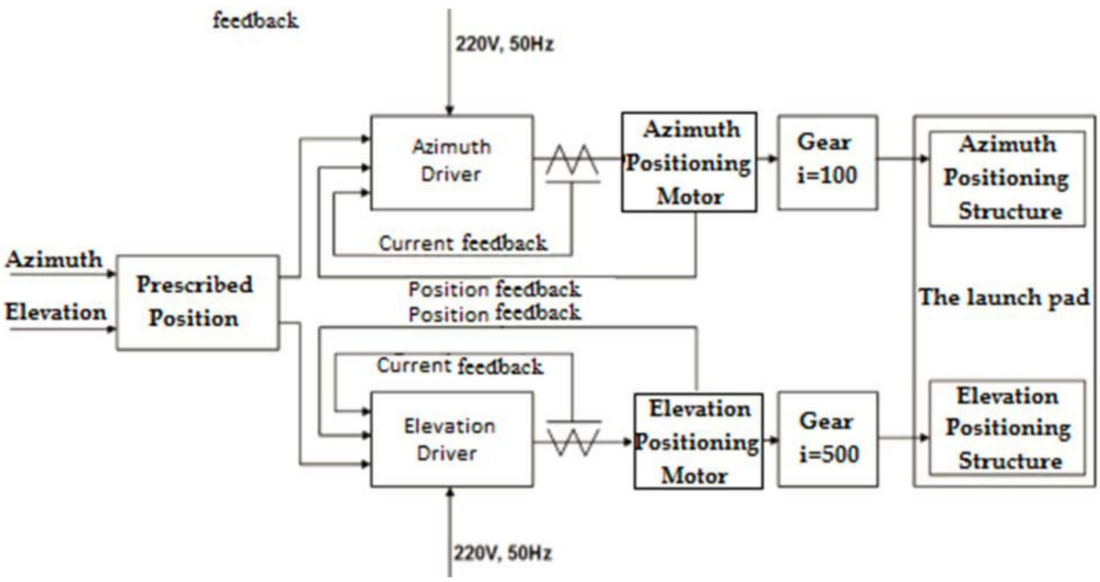


Fig.14. Structural diagram of the drive system used in positioning of the launch pad.

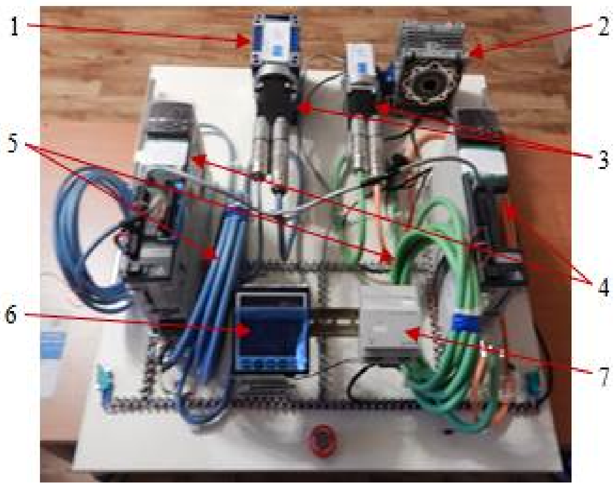


Fig.15. An experimental model of positioning system: 1- mechanical gear for elevation; 2- mechanical gear for azimuth; 3- synchronous motors; 4 – smart drivers; 5- communication cables; 6 – touchscreen; 7- DC power supply.

The system also allows for the introduction of prohibited sectors that cannot be launched. For example, the elevation angles at which missile launches are made are between 45° ÷ 85°.

The local control of the positioning system is secured by the touch screen terminal (integrated module XL4-OCS) which also uses RS-485 communication with the two intelligent drives. The same communication protocol can be utilized for the Slave terminal of the command system.

At the start, the default screen (Fig.16), allows for the proper home position of the ramp, as well as the local positioning control.

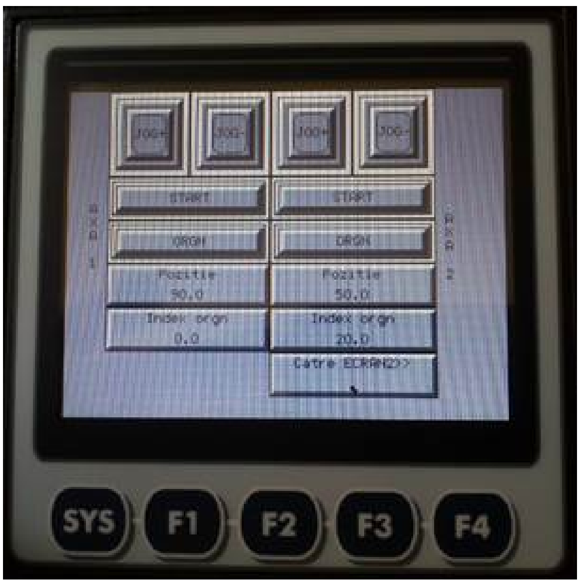


Fig. 16. Default touch-screen display.

Programming the touch screen is simple and intuitive as it is organized on the two axes: azimuth and elevation (half of screen is allowed for each axis).

V. CONCLUSION

As the power consumption of an anti-hail local unit is not constant, a solution has been adopted for photovoltaic power supply equipment using a compact photovoltaic system capable of configuring consumer-adapted energy production.

Also, the average annual radiation determined with the BlueSol software is 112.97 [kWh/m^2], and the one obtained by the measurements is 105,6 [kWh/m^2].

Based on the information obtained on the solar irradiation available at that location, it is possible to estimate the energy output of the PV system.

The system can be installed in multiple configurations, either as an independent alternative system or as a backup system, in which case it can be used as an automatic energy manager.

The photovoltaic system and the energy management system have been verified by both numerical simulation and experimental.

The positioning system has been approved by the equipment manufacturer for the Romanian national anti-hail system and the research team is currently working on a radio remote control solution for transmitting firing coordinates from the operator to the ramp.

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First coauthor – 40%
Second coauthor – 10%

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