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# Structural Monitoring of Cancano Dam with an Automatic System

Système de contrôle du barrage de Cancano au moyen d'un systeme automatique

Struktüberwachung des Cancano Damm mit einem automatischen System

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**SUMMARY**
This article describes the activity carried out for on-line checking of the behaviour of the hydroelectric power plant structures during their operation. All the measurements are gathered and checked by an automatic monitoring system located on each dam and collected together in a local processing center using a teletrasmission network.

**RESUME**
L'article explique l'activité conduite pour vérifier le comportement des structures des installations pendant leur fonctionnement. Les mesures sont réunies et contrôlées par un système automatique de contrôle installé sur chaque barrage. Une centre local rassemble toutes les mesures par un réseau de transmission.

**ZUSAMMENFASSUNG**
Der Artikel beschreibt die Aktivitäten zur Kontrolle des Verhaltens der Bauwerke in den AEM Anlagen während des Betriebes. Ein Ueberwachungssystem für die Dämme sammelt und prüft die Messdaten, welche durch ein Datenübertragungsnetz in ein lokales Verarbeitungszentrum übermittelt werden.

## 1. DESCRIPTION OF THE DAM

The Cancano dam, located in the higher part of Valtellina Valley (province of Sondrio) is situated in the complex of the Azienda Energetica Municipale (AEM) plants for water resources exploitation of the Valtellina area.

The whole complex (Fig.1) involves a catchment area of about 990 Kmq and is comprised of three dams (S. Giacomo, Cancano, Fusino), two fluvial transverses (Le Prese, Sernio), 26 water plugs and 6 idroelectric power plants.

The Cancano dam has the biggest basin in the area (basin capacity: 123 Mmc) and feeds into the cascade to the other following plants.
The basin takes water from the down-flowing, taken by the water plugs, and collected by gutter system with longitudinal development of about 70 Km.
The dam, constructed during 1953-56, is a single-curve arch gravity dam, pratically symmetrical with respect to the main section, with a pulvino foundation along the excavated profile; the height of the dam is 136 m and the development of the crest is 381 m. The main features of the dam are reported in Fig. 2

## 2. SURVEILLANCE NETWORK

Since the time of construction, the surveillance of the dam behaviour has been manually performed recording the following quantities: environmental data, temperature inside the dam body, horizontal and vertical displacements, deformation inside the concrete, joint opening, seepages through the dam body and through the rock foundation.

The schedule of the installed instruments, which comprise the surveillance network, is reported in Table 1 ; it also reports the average frequency of measurements taken by AEM. All measurement data collected are recorded on bulletins stored in the AEM archives and periodically they are manually plotted and visually checked for cronological trend in congruency and homogeneity.

## 3. BEHAVIOUR INTERPRETATION ANALYSIS

In 1980 ISMES has been requested by AEM to perform in depth investigative studies for interpreting the dam behaviour (2). A computerized database is created in which all the collected data are stored starting from the beginning of the construction.

A 3D finite element mesh of the dam was made to calculate the theoretical response of the dam to the operating loads (water level and temperature). In this way the real behaviour is analyzed by comparing it with the theoretical reference behaviour. In Figs. 3 and 4 the 3D mesh is reported showing comparison between the theoretical and the measured data. An in-depth analysis, using computer methods, have shown repetition of dam behaviour, specifically noticeble movements of the dam with a daily cycle. Also from the analysis a more in depth characterization of the foundation behaviour is required which can be further used to define a better calibration of the interpretative model parameters.

## 4. AUTOMATIC MONITORING SYSTEM

From the results of interpretative analysis and following the program of AEM towards a completed automated monitoring system that collects, stores and processes the data, in 1986 an automatic monitoring system was realized, for Cancano dam, by automating the readings of some instruments and by installing new automatic sensors. That would enable a better description of the rock foundation deformation and the thermal condition of the dam body.
The system operates daily, in a complete automatic manner, by collecting and processing the data from different sensors.

A connection between the dam monitoring system and a local center for storage and processing the data is made. The local center is able to store and process the data through the computer center of ISMES, via telecomunication, where the computerized measurement database is located.

### 4.1. Description of the automatic monitoring system

The Cancano monitoring system is a "distributed" one (3). It is composed of two Peripheral Measurement Units (PMU) placed in the dam tunnel and connected through a single optical fibre digital data transmission line to a Central Control Unit (CCU) placed in the warden house. The advantages of a "distributed" system are: higher precision and reliability of the measurements, reduction of the costs for the electric cables and for their setting up.

Fig. 5 shows a simplified block diagram of the monitoring system where the main "hardware" components of the system are pointed out:
Measurement sensors, Peripheral and Local Measurement Units, (PMU,LMU); Central Control Unit (CCU); Power Supply Unit (PSU); interconnecting lines.

The main features of each component are described hereunder.

### 4.1.1. Measurement sensors

Fig.6 shows the location of the measurement instrumentation. The already existing instrumentation network, has been enlarged adding no. 28 thermoresistors into the concrete, no. 1 communication vessel level meter, no. 10 rockmeters, no. 1 telecoordinometer and no. 1 meteorological station. Dam and foundation water leakage measurement have been automated. Three telecoordinometers and one water level meter already automated, have been connected to the acquisition system.

- Water level meter

The level meter is made of a Ryttmeyer precision balance (1 cm resolution), with pneumatic pressure transmission, completed with display and 14 bit GRAY code decoder.

- Plumbline telecoordinometer

On plumbline systems - two direct and one reverse- already working on the dam , have been installed 4 automated telecoordinometers. These are the ISMES mod. TEL 140 D optoelectomecanical unit with digital signal output on serial line. They allow to measure the two displacement coordinates with a 0.03 mm precision range.

- Communicating-vessel level meter

A communicating-vessel level meter ISMES LCM-3 has been installed in the radial tunnel at the base of the central section of the dam. The level meter vessels have a +/- 50 mm measurement range and a 0.04 mm precision within a temperature variation ranging around 10 C.

- Dam and foundation leakage measurement

The automation of the dam leakage measurement is carried out by means of two proximity sensors on the teetering tank (60 l.) placed downstream the catch water.

The foundation leakage measurement which come together in the short-plumbline well , is carried out calculating the functioning time of a pump that at maximum level, drains out water from the well. Besides a water drill meter has been installed , as to provide the water leakage measure even when these are extremely reduced.

- Rockmeter

N. 4 multibase rockmeters have been installed; N.2 rockmeters double base on the main section, with a 10 degrees inclination on the vertical (upstream-downstream) N. 1 rockmeter with 3 bases on the right edge , with 25 degrees inclination on the horizontal; N.1, as the previous one, but on the left edge. The wide base rockmeters have been automated by means of a water/air tight displacement transducer with plastic conductive resistor, 50 mm stroke and 0.1% linearity.

- Dam core concrete temperature

As to measure the dam core concrete temperature no. 28 armored thermal drills with two platinum thermic resistors housed in stainless steel sheaths, have been placed.

- Meteorological station

This consists of an instrument shelter with a sensor for the air temperature measurements and a rain gage cabin for the rainfall measurements. The temperature sensor is made of a platinum thermal resistor with +/- 0.3 C precision and provided with an electric fan device. The rain gage has teetering tank with a 1000 cmq calibrated vent 0.2 mm resolution and provided with a oil electric heater as to melt ice and snow.

### 4.1.2. Local and peripheral measurement units

The signal coming from different sensors installed on the dam are headed to the two peripheral measurement units, configured for 24 and 36 channels.

Whereas the water level meter and meterological sensor signals, are headed to the local measurement unit, installed in the same rack containing the control unit in the warden house.

### 4.1.3. Central control unit

The central control unit is made of the following components :

- computer, provided with memory modules; operating system on ROM, output/input interfaces towards peripherals;
- command and display unit made of a video-display and multifunctional keyboard;
- multifunctions interface unit, provided with local measurement unit for the meterological data acquisition and water level meter acquisition.
- printing unit
- recording unit on magnetic tape
- Interface unit towards the teletransmission device (modem)

### 4.1.4. Uninterruptable power supply unit

As to allow the system functioning also during short power black-out, the entire monitoring system is supplied through an uninterruptable group made of supplier, batteries, and one direct/alternating voltage inverter.

### 4.2. System main functions

The main functions performed by the system are summarized hereunder.

- Continous monitoring

This is the normal system function. The continous monitoring has an acquisition and control cycles with 10 min. intervals and is used for every sensor, except those which have to be read less frequently, because, being exposed to prolonged stress, are more liable to wear and tear.

- Periodic acquisition

A complete acquisition cycle is performed at fixed intervals including also those instruments which were not acquired during the continuous monitoring phase. During this phase structural checks are also triggered, by comparing the acquired data and its speed with relevant threshold levels.

- Accelerated acquisition

If required the system can be set up to activate acquisition cycle at closer intervals. This is done to have a greater quantity of data at one's disposal and to have effective check right after a particular event,as for example: earthquakes, landslides, floods or after sudden variation of certain significant quantities or measurement values.

- Required acquisition

A complete acquisition cycle (including printing and recording of the measurements) can be performed at any moment, if the user requires it.
This can be useful when carring out maintainance operation or in case of anomalyies, and also when a comparison between measurement data of sensors connected to the automated system with other measures of manually read instruments.

- Display, Local printing, teletransmission

The system is able to supply summarized printouts of measurements and checks on the system video monitor or on hardcopy printout. Such printouts can be automatically produced by the system at fixed intervals and when particular events occur. The printout content can be delivered to the Grosotto local center through an interfacing unit to the teletransmission.

- Data storage

Data can be stored on magnetic tape automatically at prefixed intervals or at the request of the local qualified user. Each record contains the ensamble of all measured values with identification numbers, time reference (date,time) and validation code.

## 4.3. Interconnection with the local and remote center

The Cancano dam monitoring system is integrated in the data teletransmission network, heading to the Grosio and Grosotto control centers.
Fig.7 shows the complete scheme of the data teletransmission network in the Valtellina area, when all monitoring systems will be installed on AEM dams and all network linking activated.

The dedicated "point-to-point" network has its two control centers in Grosio and Grosotto.
The teleoperation center is located in Grosio and it's responsable for all plants telecontrol; also the anomalyies teletransmission network connected to the monitoring system is headed here. By means of this network,information of both, structural and instrument breakdowns or anomalyies are sent in real time to the center which is supervised 24 hours a day.

The office responsable of the dam structural control is in Grosotto; the structural data teletransmission network connected to different monitoring system is headed he Thanks to this network the center receives daily updated measurement which are automatically read on the different monitoring system together with possible signalling of structural or instrument anomalyies. The local center is connected to ISMES through a telephonic line. By means of a PC the acquired data are transferred in a database to be processed. The PC terminal operates with the MIDAS database and through this PC it is possible to interrogate the database and to process locally the data, producing plots and tables by the centre itself.

## 5. FUTURE DEVELOPMENTS

AEM in cooperation with ISMES are so projecting a complete programm for the progressive automated system for checking the behaviour of the different plants using automated monitoring system and data teletransmission towards a local processing center (Fig. 7).

All the collected data will be stored in the relevant databases located in the computer center of ISMES for further elaboration.
The realization and the use on-line of theoretical behaviour models will allow the continuous automatic check of the structure behaviours during their operation.

## REFERENCE

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2. Bonaldi, Lionetti, Peano, Riccioni, "Thermal craking due to periodic temperature variation on the downstream face" - 2nd Int. Conference on numerical methods in thermal problems, Venice July 1981.

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MONITORING NETWORK

| MEASURED QUANTITIES | SENSOR | NUMBER | FREQUENCY | |
|---|---|---|---|---|
| Water level | hydrost. balance | 1 | daily | AUT |
| | levelling staff | 1 | daily | |
| Air temperature | max-min therm. | 1 | daily | |
| | electric therm. | 1 | | AUT |
| Rain fall | rain gauge | 1 | daily | AUT |
| Snow | levelling staff | 1 | daily | |
| Ice thickness | levelling staff | 1 | daily | |
| Water temperature | | | | |
| - surface | immersion therm. | 1 | daily | |
| - 5 m below surface | immersion therm. | 1 | daily | |
| Horizontal displac. | | | | |
| - crest collimation | optical collimator | 3 | weekly | |
| - 3 direct plumbline | coordinometer | 6 | weekly | |
| | telecoordinometer | 4 | | AUT |
| - 1 short plumbline | coordinometer | 1 | weekly | |
| - 1 inverted plumbl. | telecoordinometer | 1 | | AUT |
| Vertical displac. | | | | |
| - levelling network | topographic level. | 38 | semiannual | |
| Deformation | | | | |
| - casting restart | extensometer | 21 | fortnightly | |
| - dam body | rosetta ext. | 10 | semiannual | |
| - cracks | movable ext. | 64 | semiannual | |
| | extensometer | 26 | semiannual | |
| - in rock foundation | long base extens. | 10 | | AUT |
| Movement of joints | teledilatometer | 26 | semiannual | |
| Rotation | fixed clinometer | 1 | fortnightly | |
| | hydrostatic level. | 1 | | AUT |
| Temperature | | | | |
| - inside dam body | electric therm. | 60 | fortnightly | |
| - on the surface | electric therm. | 28 | | AUT |
| Seepage | weirs | 4 | daily | |
| | volumetric meas. | 1 | | AUT |
| | timer pump | 1 | | AUT |

AUT = automatic acquisition sensors

Table n. 1

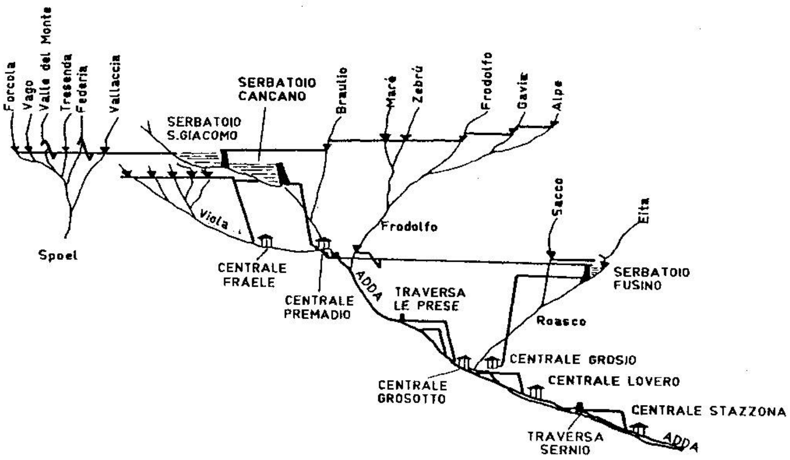


Fig. 1: AEM Plants - Altimetric scheme

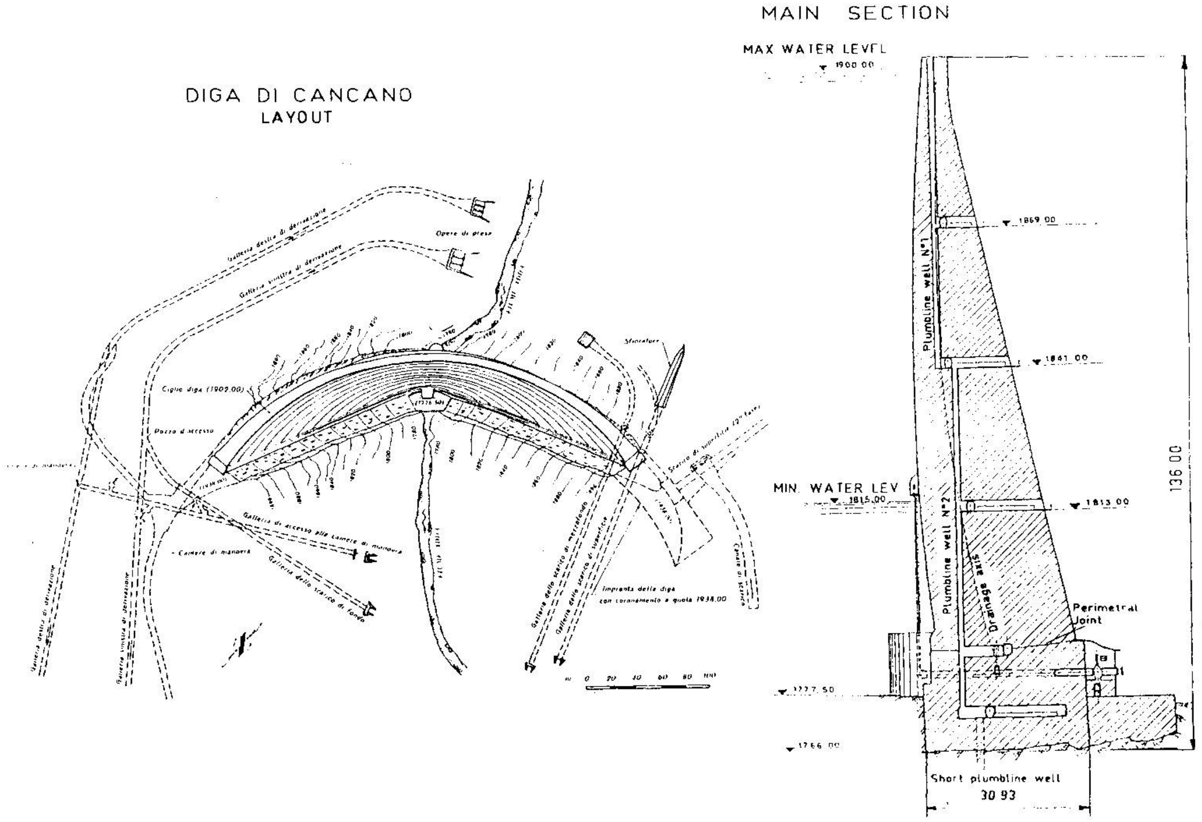


Fig. 2: Dam features

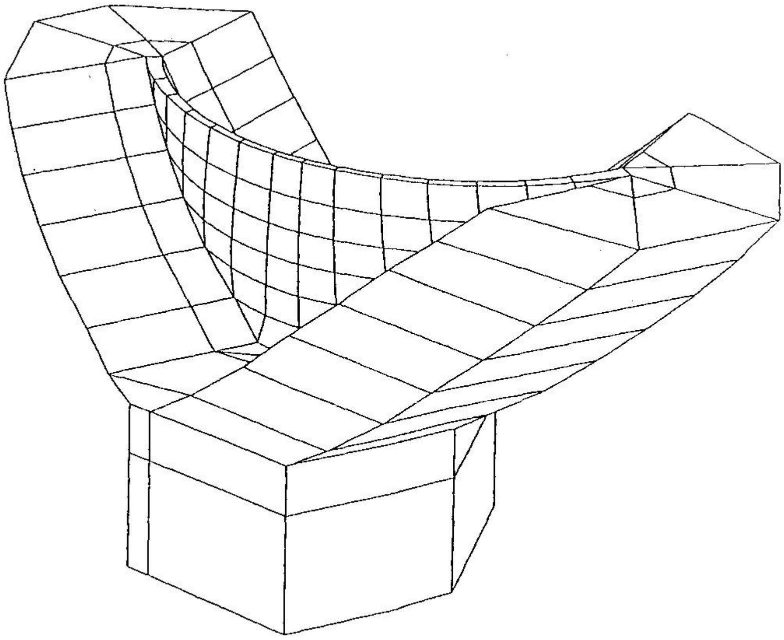

Fig. 3 : 3D mesh of the dam and the foundation

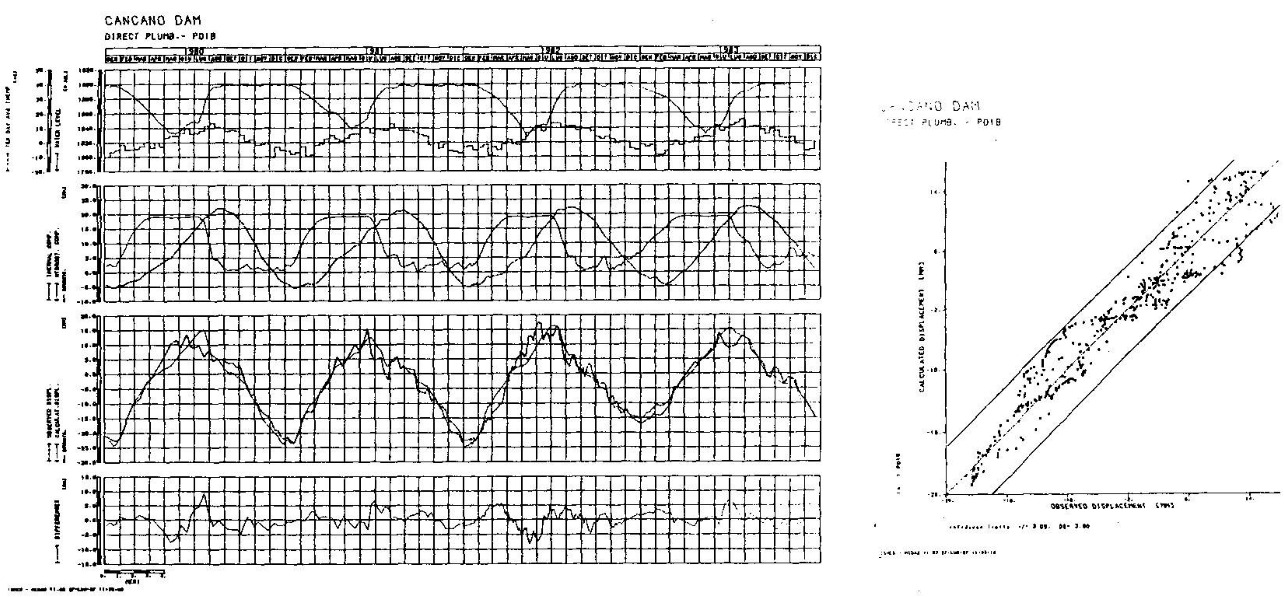


Fig 4: Comparison between measured and theoretical displacement

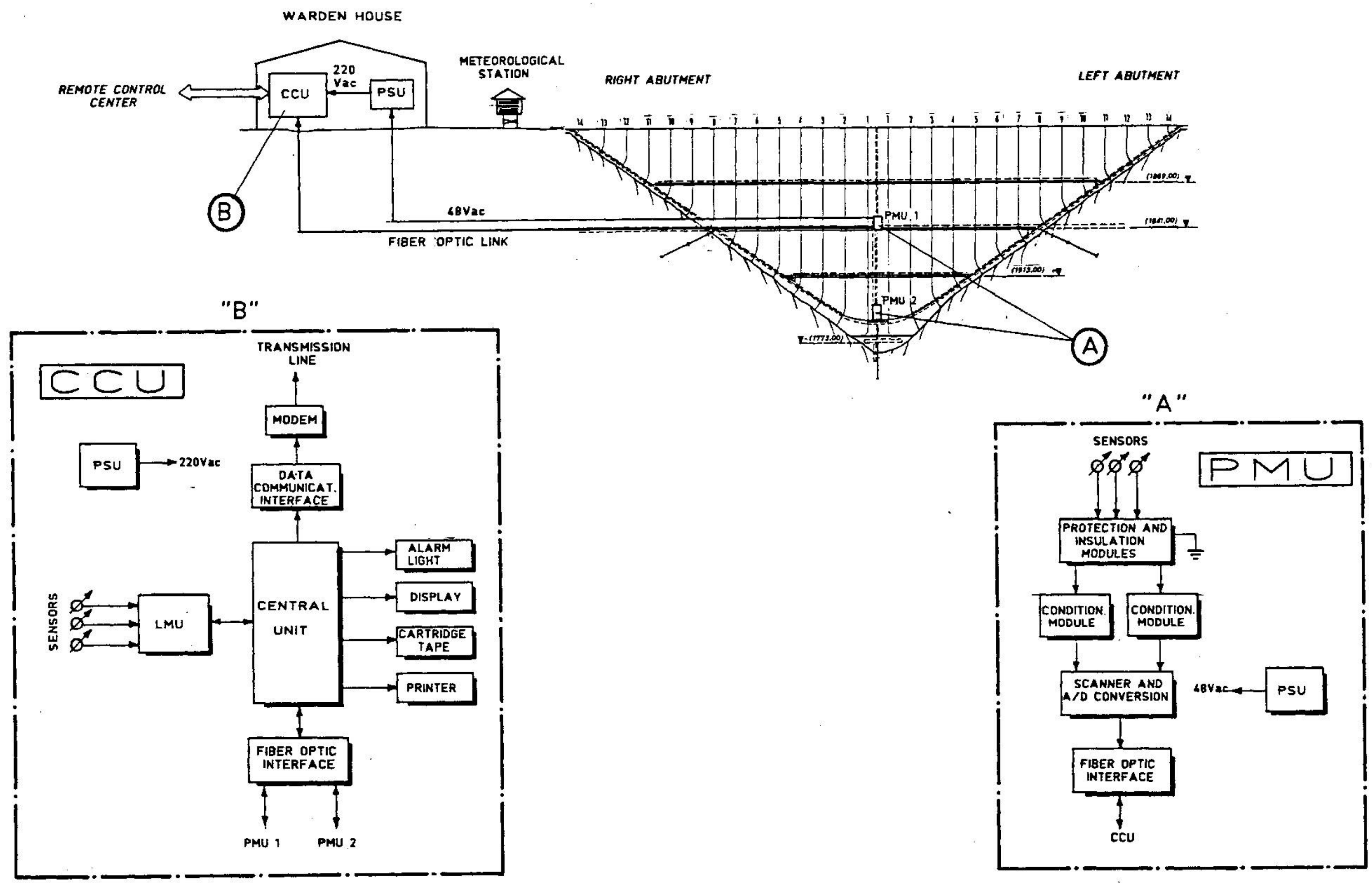


Fig. 5 - CANCANO DAM : MONITORING SYSTEM BLOCK DIAGRAM

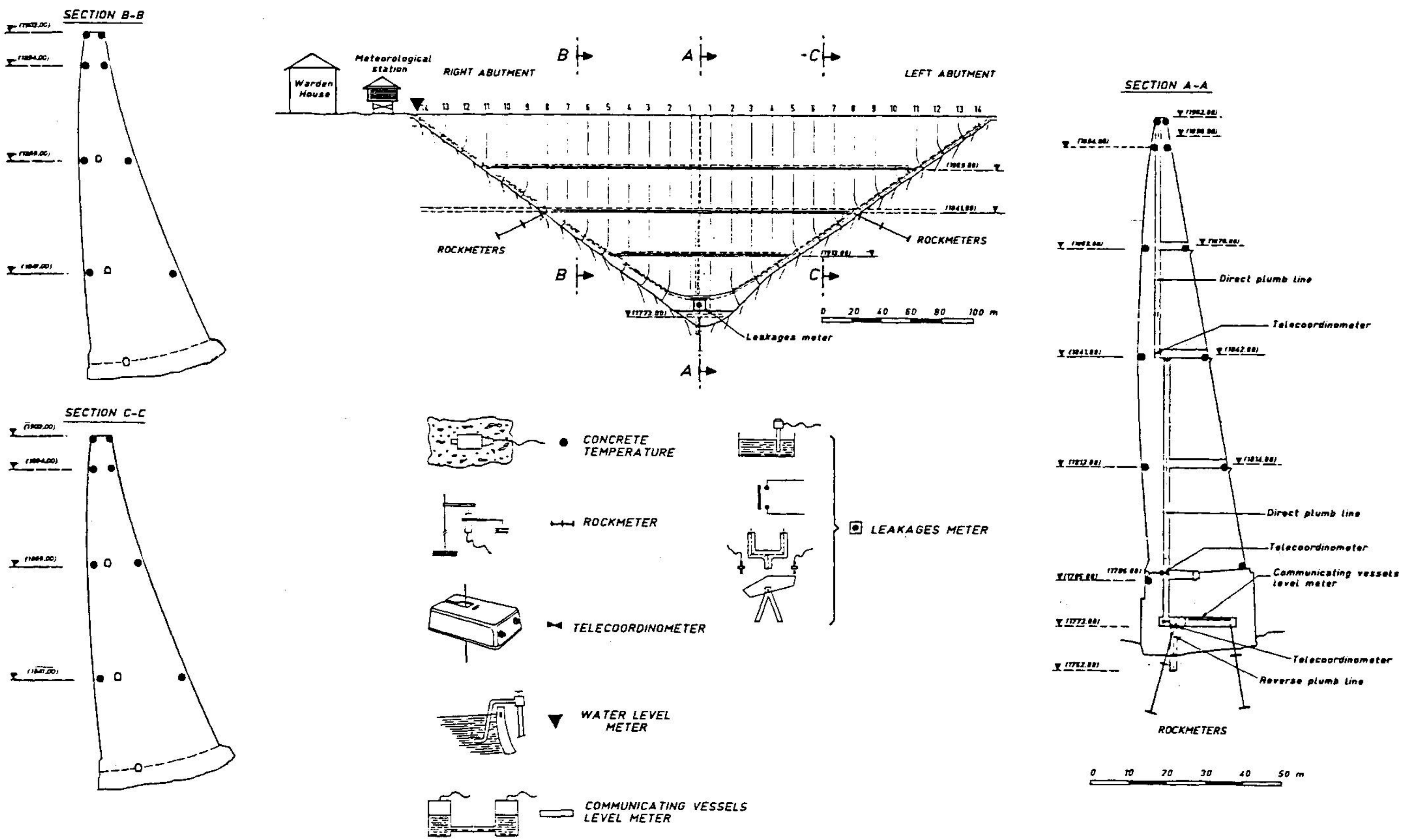


Fig. 6 - CANCANO DAM : LOCATION OF THE SENSORS WITH AUTOMATIC READING

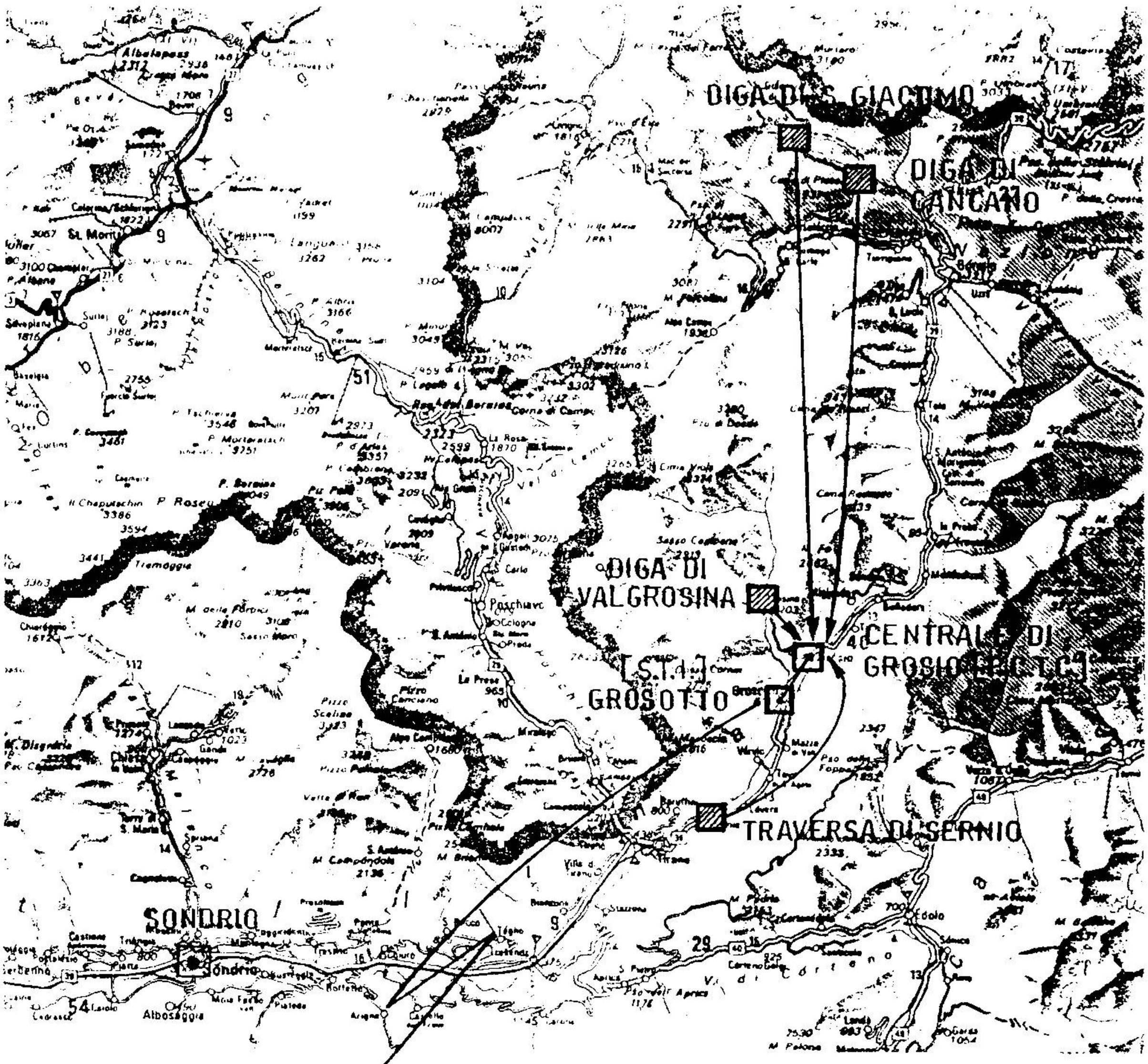



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Fig. 7: Data teletransmission network in the Valtellina Area

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