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# DISTRIBUTION AND PARAMETER CALCULATIONS OF TELEVISION CAMERAS INSIDE A NUCLEAR FACILITY

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In this work, a distribution of television cameras and parameter's calculation inside and outside a nuclear facility is presented. Each of exterior and interior camera systems will be described and explained. The work shows the overall closed circuit television system. Fixed and moving cameras with various lens format and different angles of view are used. The calculations of width of images sensitive area and Lens focal length for the cameras will be introduced. The work shows the camera locations and distributions inside and outside the nuclear facility. The technical specifications and parameters for cameras selection are tabulated.

## INTRODUCTION

A Closed circuit television system (CC.TVs); is essential to identify the cause of an alarm (intrusion process) and to determine if an alarm is true or false. With a CCTV system, security personnel can rapidly assess sensors alarms at remote locations. The CCTV system has two purposes. The first is to determine the cause of a sensor alarm. This includes determining whether the alarm is a true or false alarm. The second purpose is to provide information about an intrusion. The CCTV system is composing of several cameras at the vital areas, a display monitor at the local end, and various transmission, switching, and recording devices. Major components include: Cameras and lens, lighting system, transmission system, video switching equipment, video recording, video monitor, video controller [1]. Figure (1) illustrates a complete diagram of CCTV system.

The CC.TV system of the nuclear site is split into:

- Exterior cameras system and,

- Interior cameras system.

The Exterior cameras system provides the necessary means to conduct alarm verification and general video monitoring of the perimeter fence and adjacent areas. It possesses an additional exterior intrusion detection function, as it is part of the exterior intrusion detection system. The interior cameras system provides the necessary means to conduct alarm verification and general video monitoring inside each of the buildings and outside the buildings in their surroundings [7]. Supervision of operation activities is assigned as an additional function to the interior CCTV System. Camera system controls in security centers are manual under normal conditions when no alarms are triggered, and are programmable for automatic camera selection and VCR recording under alarm conditions (Figure 2 ).

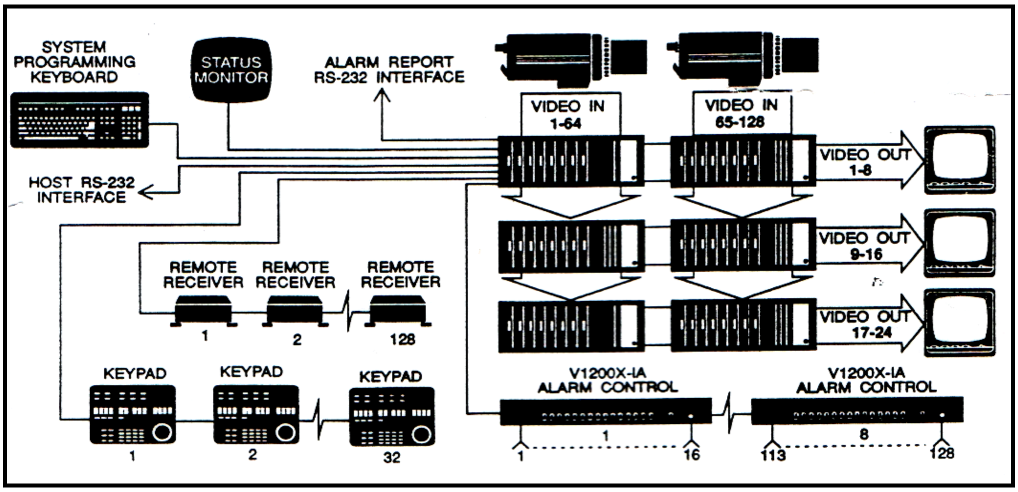


**Figure 1:** Closed circuit television system diagram.

## 1. CCTV System Architecture

Both interior and exterior CCTV systems share video matrices. These matrices provide looping, bridging, sequential and automatic alarm-triggered camera selection capabilities. Video matrices installed in security centers automatically route video signals from a requested camera position to a specified monitor. Remote control panels (RCP) let operators control pan, tilt, auto iris and alarm acknowledgment. Camera-monitor-keypad partitioning ensures that remote operators cannot control camera stations not assigned to them. RCP devices are placed in the security center [10].

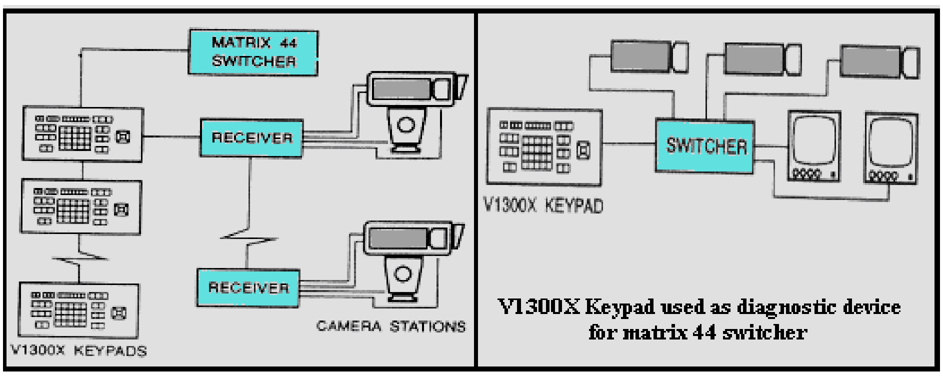


**Figure 2:** Exterior and interior CC.TV systems architecture.

Every video matrix has alarm interface units for interconnection between the CCTV system and the alarm system (AS), and a video recording device to produce a record of events. The system control includes user-friendly system programming via a computer-style keyboard and a menu-driven programming interface. The security supervisor can define or alter all system parameters [10].

### 1.1 Alarm management

When an Alarm Interface Unit senses a change in status in one of its alarm inputs, it transmits the information to the CCTV System CPU. It announces the alarm to the operator and also starts a preprogrammed response to the alarm, including displaying the video from the camera associated with the alarm on selected monitors and displaying special alarm message on the alarm monitors. The operator can designate alarm monitors and assign alarms to them. The security supervisor can enable or disable any remote keypad’s ability to acknowledge alarms. Once enabled, a remote keypad can view alarm sites and acknowledge alarms. When an alarm occurs, an operator enters the number of the alarm monitor from a remote keypad to automatically gain acknowledgment control. As the operator acknowledges an alarm, the associated alarm site video is displayed on its assigned alarm monitor. Each camera has one alarm title of up to 60 characters (3 lines, 20 characters each) for alarm site identification. The system provides RS-232 output ports for alarm event logging to printers and/or computers [8].

### 1.2 Exterior cameras system description

Black and white television fixed cameras are mounted in between peripheral wiring and external moving cameras, located at the plan view corner of the perimeter. Inside the reactor building fixed cameras are exists to cover all inside areas. The system has automatic alarm-to-video display capability and motion detection capability. Black and white TV cameras are mounted to allow a complete visibility of the clean zone between peripheral fences (by means of fixed cameras). The Exterior system consists on fixed cameras for a general inspection and Pan-Tilt and Zoom (**PTZ**) cameras for a detailed observation. The control system displays cameras' information on Security Centers’ monitors in sequence [3].

#### 1.2.1 Exterior cameras selections

Black and white cameras of 1/4-Inch format are used. The selected model is VC2130-24 from VICON type or equivalent. They have a high-sensitivity charge-coupled-device (CCD) image sensor and solid-state circuitry that provide long life and high reliability. All cameras have auto iris lenses, low light capability, output level control and self identification generator. An incorporated automatic linear electronic shutter responds automatically to changes in light level by increasing or decreasing the integration period of the chip. The linear shutter range is 1/50 - 1/10000 second.

Lens size is chosen according to supervision area of each one of the cameras [9].

#### 1.2.2 Camera parameters calculations

Many cameras' parameters, which consider important factors in designing CCTV system, should be computed such as the followings:

(1) Lens Format,

(2) F-number,

(3) Lens focal length calculation,
(4) Angle of view calculation, and
(5) Width of images sensitive area.

### 1.2.2.1 Lens focal length and subject dimensions calculation

The length format size defines the maximum usable image created by the lens. Standard lens formats are matched to the format of the camera selected.1/4-Inch format will be selected for the exterior cameras are used inside the perimeter fence. Focal length is the single most important factor in proper lens selection. It determines the relative magnification of the object. Since the format of a lens is known, the focal length will define the angular fields of view (horizontal and vertical angles covered by lens), thus defining the width and height to the field of view for the camera for any object distance [5]. Figure (3) shows the lens focal length and angle of view.
According to the external perimeter fence dimensions, the wide image area is 10 meters (distance between the two double fences). The long distance of one side of perimeter fence is 400meters. If we divide this distance into three zones each zone become 133.333 meters, this distance considers the longest distance between the object and camera [8].

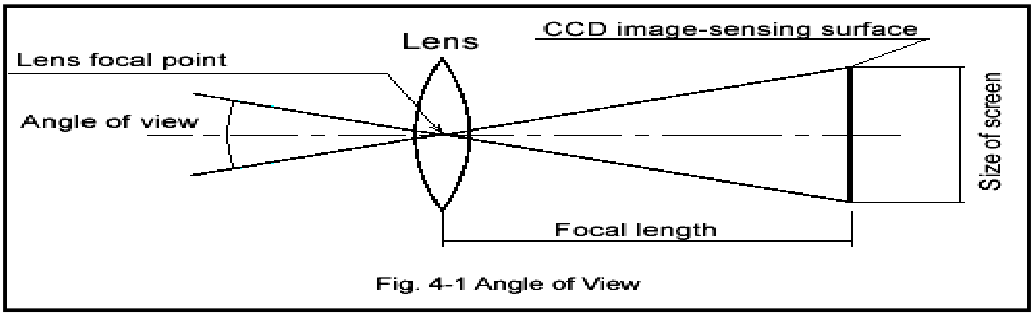


**Figure 3:** Lens focal length and angle of view.

Lens focal length (mm) of the camera can be obtained from the formulas:

- **1/3'' inch Type:**

$$W = 4.8/f \times L\ (m); \qquad H=3.6/F\times L\ (m) \qquad (1)$$

- **1/4'' inch Type:**

$$W = 3.6/f \times L\ (m); \qquad H=2.7/F\times L\ (m) \qquad (2)$$

where:
W: Width of subject
H: Height of subject
L: Distance between subject and camera (figure 4).
F: Lens focal length (mm)

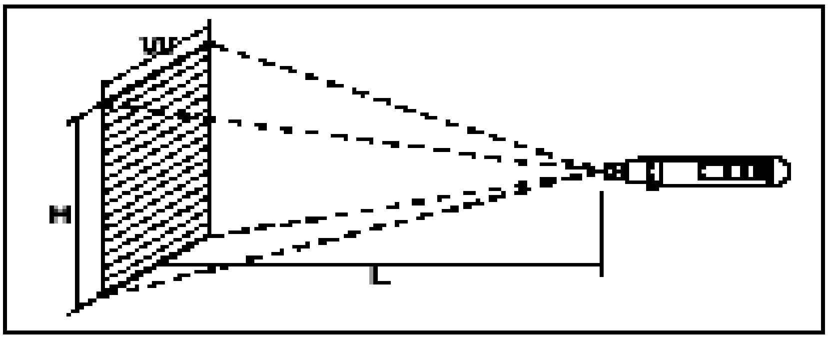


**Figure 4:** View field.

As mentioned above a 1/4-Inch format camera is used. By substituting on (2) formula Lens focal length can be obtained as follows:
10 (meters) = 3.6/f ×133.333 (meters)   f = 47.99
According to the manufactured focal lens types founded we choose

**f = 50mm**

#### 1.2.2.2 F-Stop number calculation

**F-number** is **a**n important lens parameter is its aperture setting called an f-stop, which is the lens' measure of its ability to gather light. The smaller the f-stop, the light is admitted; therefore, a small f-stop (1.2 to 1.8) is desirable for exterior assessment applications. The number is the ratio of the lens focal length to the aperture opening in mm [10].
**f-stop** is ratio between lens focal length (50mm) and aperture opening if we have aperture opening is 27.7 f-stop number is :

**F-stop = 1.8**

Height (H) of the subject can be computed by formula (2)

H = 2.7/F × L (m)   H = (2.7/50) ×133.33

And, **H = 7.19**

The image area (W×H) is = 10 width ×7.19 height as illustrated in Figure (6).

#### 1.2.2.3 Width of images sensitive area calculation

The width of image sensitive area can be calculated from the equation:

$$\mathbf{D = W\,(f/\mathit{w})} \tag{3}$$

where:
D: distance from the camera (m)
W: is width of field of view (m)
f : is focal length of lens (mm)
*w*: is width of images sensitive area (mm)
Computation of the width of images sensitive area by substitute on (3) formula:
133.33 = 10 (50/*w*)

***w* = 3.7**

#### 1.2.2.4 Angle of view calculation:

The angular range covered by a camera is referred to as its “angle of view” and is determined by the focal length of the lens and the size of the imager (CCD) on which the picture is formed. The angle of view is expressed by the following formula:

$$\theta = 2\tan^{-1}\left(\frac{I/2}{f}\right) \tag{4}$$

where:
θ: Angle of view
I: effective dimension of CCD (mm)
f: Lens focal length
By substituting in formula (4) by lens focal length **50mm** and effective dimension of CCD **4.6mm** (selected technical specification of model VC2130-24 from VICON) the angle of view becomes is:

$$\theta = 5.26 \text{ degree}$$

### 1.2.3 Exterior cameras locations

From the previous calculations we puts two moving pan-tilt zoom cameras at the two corners of each perimeter fence side to cover **267** meter and puts two fixed cameras on the middle distance, to cover the remained areas. The image area (W×H) is = 10 width ×7.19 height. Pan-tilt-zoom cameras are placed on corners of the perimeter fence and others significant points of the site areas. All cameras are linked to a central CCTV programmable matrix. Pan-tilt and zoom units will have 350° panoramic movements and full ±90° up-down movement capacities [9].

A total of eight fixed cameras and five PTZ cameras should be placed as the Exterior CCTV System. The distribution of cameras is shown in figure (5).

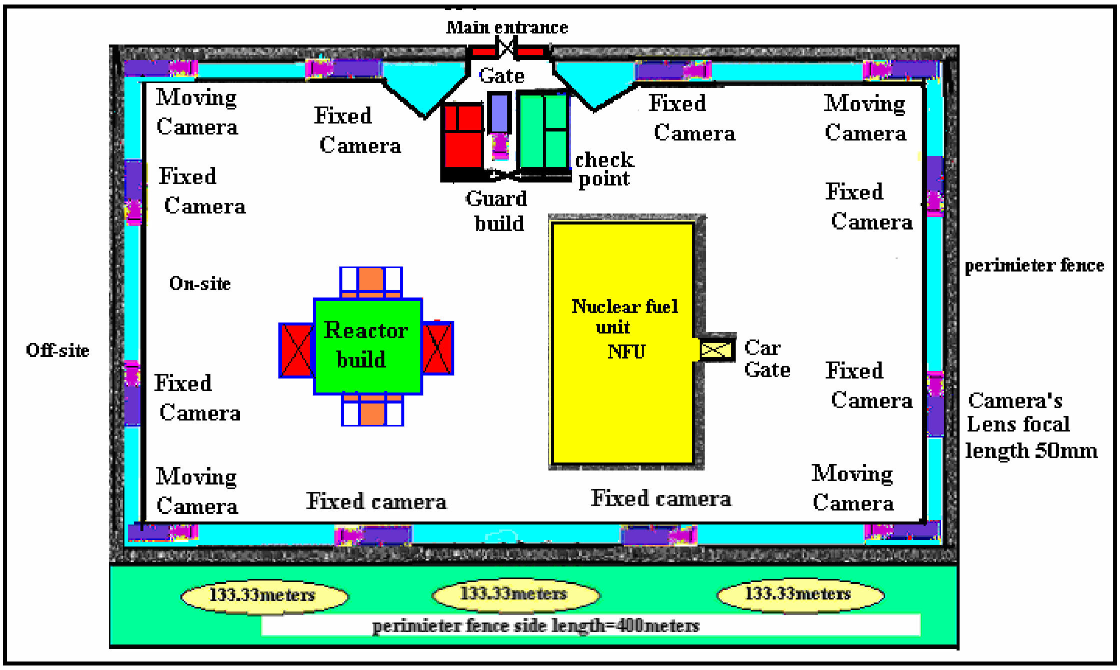


**Figure 5:** Peripheral fence camera's distributions.

As shown in the figure, the Fixed cameras are located on the isolation zones of the double fences and installing on high iron steel support its height reach to 9 meter [3]. It is higher than the electrical columns founded on the zone. To insure the system functioning during 24 hours a day an illumination system is provided. It is based on high pressure sodium vapor lamps. This system’s power supply is through an UPS, providing day and night operation. The double fence consists of four sides; each side must contain 4 cameras as a minimum number required and distributed as follows:

Thirteen camera units should be used to cover the external perimeter's areas and their distribution as follows:

- **8 fixed cameras**: two cameras per side (2×4 sides) should be located at the middle distance of the perimeter fence and their view is in opposite direction to make interference on image viewer area to protect them.
- **5 moving cameras:** four cameras should be located at the corners of each side. One pan-tilt zoom moving cameras located on the guard building of the research reactor facility. The cameras will be used to covers 1600 meters around the perimeter fence of the site. The final results are illustrates in table (1).

**Table 1:** External camera parameters results.

| Item / Area | Lens format | Lens focal length (mm) | F-Stop number | Height (H) meter | Images sensitive area (*w*) | Angles of view (θ) | Number of cameras |
|---|---|---|---|---|---|---|---|
| **Isolation zones** | **1/4'' Inch** | **50** | **1.8** | **7.19** | **3.7** | **5.26** | **13** |

## 2. Interior Cameras System Description

The interior system provides the necessary means to conduct alarm verification and general video monitoring inside the research reactor building. It consists on general application black and white television cameras placed in the interior and also in relevant exterior locations of the buildings. Cameras location is selected from a security or operational point of view.

### 2.1 Internal zone's dimensions

The research reactor building floors are repeated and it contains four inner zones (Z01, Z02, Z07, and Z12) for each floor; three locations inside reactor rooms and reactor hall area, all areas must be covered by a fixed camera. Figure (6) shows the research reactor (RR) building second floor. Its internal zones and rooms are illustrated and they have the following dimensions

- **Areas and zone's dimensions:**

| | |
|---|---|
| Zones (Z01, Z02, Z07) | (3 × 10 meters) |
| Zone12 (Z12) | (4 × 5 meters) |
| Zone15 (Z15) | (3 × 6 meters) |
| Room2 (R2) | (4 × 8 meters) |
| Room3 (R3) | (4 ×5 meters) |
| Room1 (R1) | (4 ×15 meters) |
| Reactor hall area | (15 × 25 meters) |

### 2.2 Interior cameras selections

Black and white fixed cameras of **1/3'' inch** format are used. The selected model is VC2130-24 from VICON type or equivalent. Lens size is chosen according to supervision area of each one of the cameras.

### 2.3 Interior camera parameter calculations

### 2.3.1 Lens focal length (f) and subject dimensions calculations

Lens focal lengths (**f** mm) and Height of the subject (**H**) of the fixed cameras can be obtained from the formulas (1) by using 1/3" inch format type:

f=16mm H = 2.25 meters for Zones 01, 02, 0

f= 9.6mm ~ f=10mm H = 2.8 meter for Z12, Rooms

f= 8mm H = 11.25 meters for Reactor hall area

Note that Z12 near to the area of the inner rooms so that the cameras specifications for the inner rooms will be choused for Z12.

The image area (W×H) is = 3 width ×2.25 height

= 4 width ×2.8 height

=15 width ×11.25 height

### 2.3.2 F-Stop number

As mentioned above f-stop is ratio between lens focal length (f mm) and aperture opening if we have:

Aperture opening is 13.2 F-stop =1.2 for Zones 01, 02, 07

Aperture opening is 7.2 F-stop =1.3 for Z12, Rooms

Aperture opening is 4.6 F-stop =1.7 for Reactor hall area

### 2.3.3 Width of images sensitive area

The width of image sensitive area can be calculated from the equation (3).

$w$ = 4.8 for Zones 01, 02, 07

$w$ = 5 for Z12, Rooms

$w$ = 4.8 for Reactor hall area

### 2.3.4 Angles of view calculation

The angle of view can be calculated by substituting in formula (4) by lens focal length 16mm, 10mm, 8mm and effective dimension of CCD **2.3mm** (selected technical specification of model VC2130-24 from VICON) the angle of view calculation results are:

$\theta$ = 8.2 for Zones 01, 02, 07

$\theta$ =25.9 for Z12, Rooms

$\theta$ =32 for Reactor hall area

All interior cameras parameters results are shown in table (2)

**Table 2:** Interior cameras parameter results.

| Item / Area | Lens format | Lens focal length (mm) | F-Stop number | Height (H) meter | Images sensitive area *(w)* | Angles of view (θ) |
|---|---|---|---|---|---|---|
| **Zones 01, 02, 07** | **1/3'' Inch** | 16 | 1.2 | 2.25 | 4.8 | 8.2 |
| **Z12, Rooms (1, 2, 3)** | | 10 | 1.3 | 2.8 | 5 | 25.9 |
| **Reactor hall area** | | 8 | 1.7 | 11.25 | 4.8 | 32 |

## 2.4 Interior cameras locations and minimum requirements

**13 fixed** cameras per floor should be used to cover the internal areas of the reactor building floors and their distribution and lens focal length as follows:

- 4 cameras units should be located inside the reactor hall (f=8mm)
- 4 cameras units should be located inside the 3 inner rooms R1,R2,R3 (f=10mm)
- 5 cameras units should be installed at the inner zones01, 02, 07, 12, 15 (f=16mm)

Figure (6) shows the fixed cameras locations should be installed onside the reactor building's floors [6].

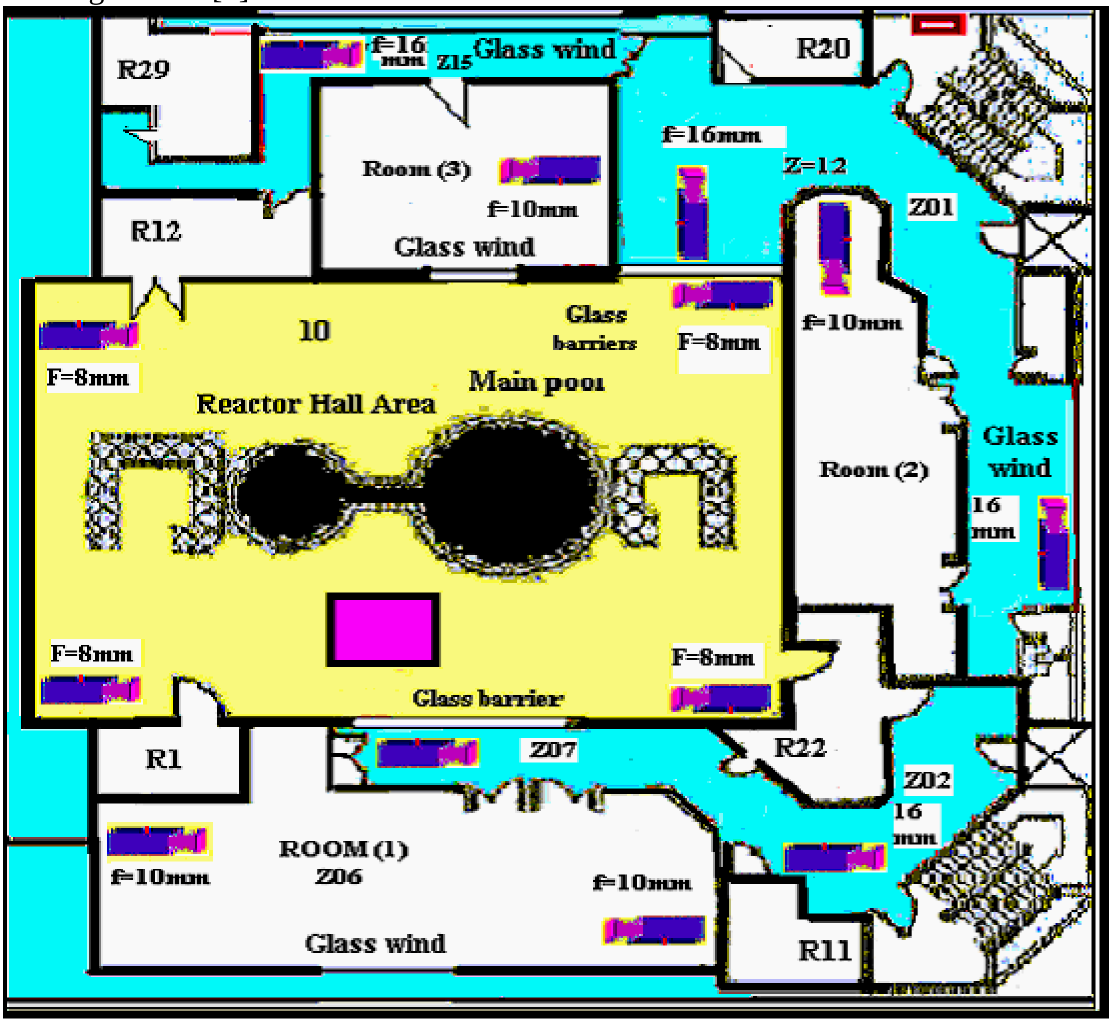


**Figure 6:** Research reactor building floor cameras distributions.

## CONCLUSION

- A calculation of camera's parameters and its technical specifications is presented for a nuclear facility. A distribution of the cameras locations inside and outside the nuclear site is explained and worked depending on the calculated camera's parameters and specifications. Fixed and moving cameras with various lens format and angle of view are used.

- The results shows there are 13 fixed cameras 1/3 inch format are used inside the nuclear facility with 8, 10,16mm focal lens to cover the internal zones and areas dimensions of the reactor building floors.
- Also there are two fixed cameras per side (2×4 sides), 1/4 inch format, with 50mm focal lens should be located at the middle distance of the perimeter fence and their view is in opposite direction to make interference on image viewer area to protect them. Four moving cameras should be located at the corners of each perimeter side. One pan-tilt zoom moving cameras located on the guard building of the nuclear complex. The external fixed and moving cameras used to cover1600 meters around the perimeter fence of the site.

## REFERENCES


[1] Marry Lynn Garcia," The Design and Evaluation of Physical Protection System", *Butterworth-Heinemann, Elsevier Science*, USA, (2001).

[2] M. Maki, C. Hill, Senstar-Stellar Corporation, C. R. Malone, US Army Engineering Research and Development Center, "User performance Testing of the Perimitrax Buried Cable Sensor", 0-7803-5247-5/99, (1999) *IEEE*.

[3] M. E. Kuhl, N. M., Steiger, F. B. Armstrong, and J. A. Joines "A conceptual architecture for static features in physical security simulation" Proceedings of the Winter Simulation Conference, (2005).

[4] Military handbook 1013/1A, "Design Guidelines for Physical Security of Facilities", USA, 9 October, (1987).

[5] 18th International Training Course, "Physical Protection of Nuclear Facilities and Materials", Sandia National Laboratories, Albuquerque, New-Mexico, USA, (2004).

[6] Safety Analysis Report (SAR) of Safari Reactor of South Africa, "Security system basic design", (1999).

[7] James D. Williams, "Physical Protection System Design and Evaluation", *IAEA-CN-68/29*, Vienna, 10-12 November (1997).

[8] Closed Circuit Television Systems Fundamentals Course", *TOA Electronics*, Inc., USA, (2005).

[9] Intelligent Transportation Systems (ITS)"Closed-circuit television (CC.TV) cameras design manual" December, (2000).

[10] Stanislav, Utochkin, CCTV-Cad.com "The principles of CCTV design in Video-CAD" issue 36 – (2006).

[11] Donnie D. Glidewell, "Considerations for Use of Physical Protection System Components in International Safeguards Applications", *Esarda Bulletin No. 32*, March (2004).