

**APPROVAL PAGE****DEVELOPMENT OF JOS TV BROADCASTING STUDIO RELIABILITY  
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**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE  
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ELECTRONICS ENGINEERING UNIVERSITY OF NIGERIA, NSUKKA.**

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## **CERTIFICATION**

Odi Josiah Ihotu, a master's degree postgraduate student in the Department of Electronics Engineering and with registration number PG/M.ENG/11/59434 has satisfactorily completed the requirement for the award of Master of Engineering (M.ENG) in Electronics Engineering.

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### **DECLARATION**

I, Odi Josiah Ihotu, a postgraduate student of the Department of Electronics Engineering, University of Nigeria, Nsukka, declare that the work embodied in this thesis is original and has not been submitted by me in part or in full for any other diploma or degree of this or any other University.

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ODI JOSIAH IHOTU

DATE

## **DEDICATION**

This work is dedicated to the Almighty God and my Parents, Mr. and Mrs. Odi.

## ACKNOWLEDGEMENT

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## ABSTRACT

The broadcasting stations in Nigeria often encounter sudden failures, which results in loss of signal that causes the station to experience down-time. Causes of the failures could be traced to the issues that range from erratic power supply to degradation in the studio equipment. Each failure and its consequent down-time influences the reliability of the station. In our environment (Nigeria) reliability does not only depend on the established parameters, instead it includes parameters such as lack of superior equipment and equipment maintainability. This is the more reason why the definition of reliability for a sensitive system such as the television station in our context is very important. In this work, the Jos television broadcasting station (NTA Jos) was examined in order to develop a reliability model with which the station's broadcasting studio's reliability can be defined, at any point, with high precision. The TV broadcasting studio configuration was therefore determined and modeled analytically. The model was simulated and the simulation results analyzed. Analysis results show that failure and restoration rate is expected to influence reliability significantly. Within the period of reliability assessment, analysis of the model shows that Jos Broadcasting studio is expected to experience an average equipment failure rate of 0.0001687 units per hour with negligible restoration rate that resulted to mean reliability of 0.33%. It was established also, that the level of equipment redundancy influences reliability to a significant extent. The modified model with added redundancy as opposed to that representing the studio, showed a reliability disparity of 1.04% indicating a 382 hours gain on down-time.

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background of the study

Pleasure and convenience had improved ever since technology advanced into reproducing in our homes the exact video, audio and motion pictures displayed several kilometers away. The variation and intensity of signal's continuous succession is simultaneously reproduced in our home over space and time[1]. We will never be able to enjoy the prospect of an efficient broadcasting system if the concept of the reliability of equipment is not adequately considered.

Generally, the subject of reliability has become the fire upon which the flame of security, confidence and trust is developed round the clock. Engineers began to investigate further into the subject of reliability in the 1950's taking precedent from the failure of the first American rocket and commercial Jet aircraft: the British de Havilland comet. Life testing was part of this engineering interest. And Landmark contributions were made in this direction [2]. Nevertheless, reliability theory began to be treated as a separate subject in 1961 [3, 4]. Complex structures have been modeled accurately due to the benefit of physical reliability from the increasing computing power of reliability science [5, 6, 7]; so that great strides at designing and developing spacecraft such as the space shuttle was successful. These achievements resulted from the emphasis on risk management through the instrumentality of maintainability, reliability, system safety and software assurance [8]

Today, lives are suspended in oblivion under the influence of hospital anesthetic, so that heartbeats and blood pressure could be monitored with high precision equipment, poor reliability of such equipment is death sentence. Human being and properties are often conveyed to different destination on a very high altitude and velocity using commercial aircraft or through Terrestrial vehicle, all these will never be possible if the associated subsystems of the vehicle system were not reliable[9].

Military and civilian aircrafts are directed by airport communication towers for safe landing. Missiles navigate through long distances to specific pre-determined geographical points by computer control system [10]. In most of these cases unreliable subsystem equipment is a deadly trap looking for opportunity to destroy.

In our broadcasting station trust and satisfaction is gradually fading away. The question, "why does the TV signal often fail?" is a very popular question, a bone of contention in the broadcast world and specifically for TV users. These failures could be connected to the reliability of the equipment involved in the broadcast and their configuration.[11]

This is the more reason why this research presents the answer to this frustrating interruption of signal flow often encountered in the broadcasting station. This thesis developed a reliability model from the studio equipment using series and parallel reliability configuration. The resultant analytical model was compared with another model analyzed from the reconstruction of the same configuration. The modified model is a series system with parallel subsystem configuration. The outcome of employing the methodological strategy developed in the course of this work displayed the vulnerability of the studio to sudden failure. The reliability curves plotted emphasize the importance of the application of redundancy in order to reduce the frustrating interruptions of signal flow.

## **1.2 Aim of the Study**

The aim of this study is to develop a reliability model from the reliability configuration of an operational broadcast station (Jos NTA TV station) such that; the reliability, failure rate and restoration rate of Jos TV broadcast station can be determined at any point with high precision; also to be able to determine the reliability of other broadcasting studios using the same methodology.

## **1.3 Statement of the Problem**

The inconveniences of sudden failure from television broadcasting stations increase significantly due to so many contributory factors, ranging from human errors on the equipment to extreme operating condition. These are in various forms: Electronic parameters, such as voltage, current and frequency, Environmental parameters, such as temperature, humidity and vibration, Mechanical adjustments, such as dial settings and clearances, Faulty inputs, such as gas, and water. [12]

The effect of erratic electricity supply is also a major limitation, in most cases, alternative sources of power supply is made available. The alternative source too, is a problem owing to the cost of operation and maintenance. No matter how technical the problem resulting to failure in the system becomes, the effect obviously retard the efficiency of the associated reliability configuration of the broadcasting studio. This failure results to abrupt interruption of broadcasting signal even in occasions where it can be very costly.

If for instance, two or three states are linked together to air views for matters under review during network programs. It is very discouraging for one of the stations to break the flow because of the failure of its equipment. Another example can be seen from the inability of a station to announce time sensitive information due to failure of its equipment. Such limitation could increase the loss of life and property during inter-ethnic crises, riot or natural disaster.

In this research work, the studio configuration was modeled analytically to determine the rate per precision at which equipment failure can be predicted. The failure mode of the configuration was detected from the reliability configuration analysis. The solution proffered was the optimization of the configuration against failure by using highly reliable equipment and the application of redundancy where necessary.

#### **1.4 Objectives of the Study**

The results and method of evaluation obtained from this research work will help Engineers, Technicians and operators of broadcast stations to:

- I. Guide resource allocation process in assigning resources to sections of the broadcast systems bearing in mind that some sections may require high equipment reliability than others.
- II. Permit complete overhauling of a set of old equipment when appropriate redundancy is applied, for the implementation of better technology at the TV station.
- III. Implement the associated redundancy scheme which also prolongs the lifespan of the equipment and protects their efficiency.
- IV. Reduce the stress associated with maintenance and control while meeting the demand of reliability.
- V. Make available better condition for evaluation, recording of failure and restoration rate of broadcast equipment and providing better opportunity for market search and purchase recommendations.
- VI. Above all, to develop a reliability model through which the reliability of Jos Tv station can be determined and also the reliability of other broadcast stations can be achieved using the same methodology.

#### **1.5 Scope/Limitation of the study.**

- I. Technological advancements have conditioned equipment to well arrange irreparable segmentation of micro-electronic elements and slots made up of microprocessors and

electronic component in the form of integrated circuits. The conspicuously visible discrete kind of component system is fast fading away. A digital transmitter for instance, may comprise of slots for system stages incorporated as panels that can be removed and replaced in event of fault. Smaller parts of the digital transmitter as well as parts of other equipment are constructed in similar packaging. Therefore this study may not be able to disclose in details the reliability of all slots representing the stages of the composite equipment because of the complexities that may be associated with it. This is the main reason why the study considered for instance the transmitter as a single subsystem in the entire system of the broadcast station.

- II. This research did not identify the quality or capacity of the broadcast signal for improvement, but analyses and qualify the reliability of configurations as basis for evaluation and sustaining of broadcast signal satisfactorily.

Every electronic gadget utilized in the signal processes at the station is composed of component such as transistors, resistors, capacitors, inductors and others either in the form of integrated circuits (IC) or at discrete component level (element level). This research therefore does not consider reliability at element level.

## **1.6 Methodology of the study**

The research methodology proceeded with the presentation of the configuration for plateau state broadcast studio. The studio equipments were classified according to series and parallel reliability format, based on how they affect the failure of the entire system. A reliability configuration was constructed, analytically modeled and simulated. In order to enable the adequate comparison, the reliability configuration was reconstructed, having active redundancy for all its subsystem and analyzed in similar manner. The offshoot of the analysis of the studio was an expression for the reliability of the broadcast station, with emphasis on the importance of subsystem redundancy.

## **1.7 Organization of the work.**

This research work is arranged in such a way as to give the reader a view of the methodology that can be employed in order to fully explain, analyze and provide adequate recommendation for broadcast station reliability configuration. Chapter one introduces the work. Chapter two is divided into two parts. The first part presents TV broadcast station physical architecture. It describes the operations and reliability of TV broadcast stations. The second part presents published work on system reliability and other related literature. Chapter three is made up of the methodological strategy employed to achieve

reliable results, such as the reliability configuration construction and its analytical modeling. Chapter four presents the results from the analysis and simulation. It uses the equipment's average running hours and number of failures to display the reliability of the station under review. Chapter five presents the summary, conclusion and recommendations for further work in the area.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Introduction

The reliability, reliability model, failure and restoration rate of NTA Jos broadcasting studio are the main focus of this research work. The literature review of this research also captures the broadcasting equipment and the physical architecture of equipment's network in a typical TV broadcasting station. This involves the interconnection of equipment that enable easy signals processing and movement within the Studios, Studio control rooms and Master control room. Finally, related works on system reliability along with other relevant literatures are presented.

#### 2.2 A typical physical architecture of TV broadcasting Studio Equipment.

The physical architecture of the broadcasting studio used in this research is divided into four parts. Figure 1 represents the four sections of the TV broadcasting studio which are the program studio, News broadcasting studio, Studio control rooms and Master control room. The Studio control rooms and the Master control room control the production of signals. They also direct the signals that make up the images seen on TV receivers. The transmitter is the eventual energizer that gives the signals the ability to reach the expected destinations of the various home TV receivers. [14]

The program studio is composed of four microphones, three cameras, a teleprompter and one feedback monitor from the production control room. The news broadcasting studio is equipped with two microphones, two cameras, and a monitor for feedback from the control room. The program control room is made up of the video mixer, audio consol, camera control unit CCU, character generator CG, recorders (record.), and monitors on monitor wall, headphones and a speaker. The news broadcasting studio control section also has similar equipment as the production control room as shown in figure 1.

The master control room represented in the figure 1 is fashioned in such a way as to create room for the flexibility desired of a typical broadcast station. The number of racks to be used is dependent on the number of equipment, the frequency of usage and the station's equipment installation plan. The master control room also contains computer for storage of programs, workstations, video switcher,

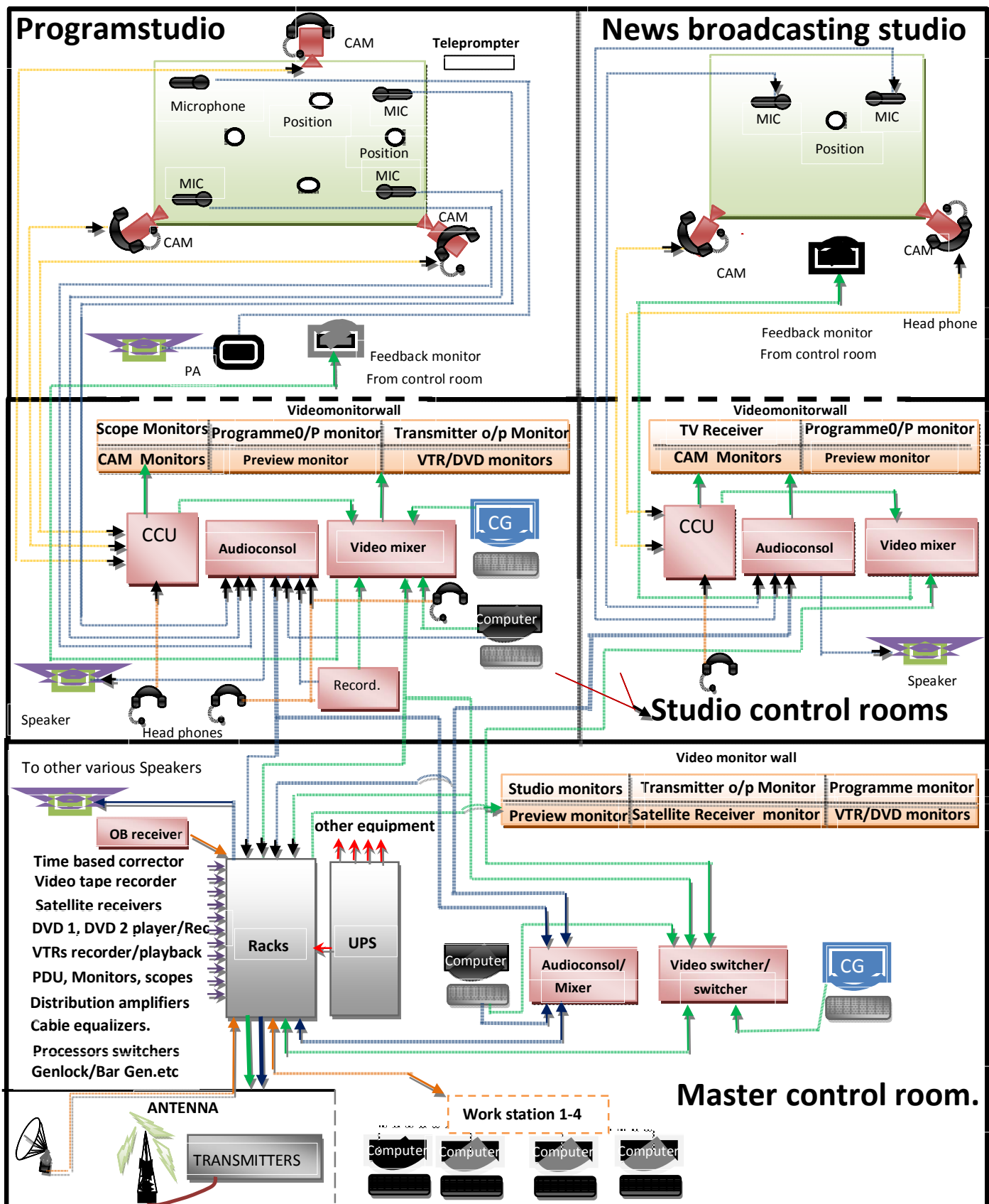


Figure 1. The physical architecture of a typical broadcasting station

audio consol, character generator and a centralized UPS that keeps the station's technical equipment on a standby when switching to an alternative power supply.

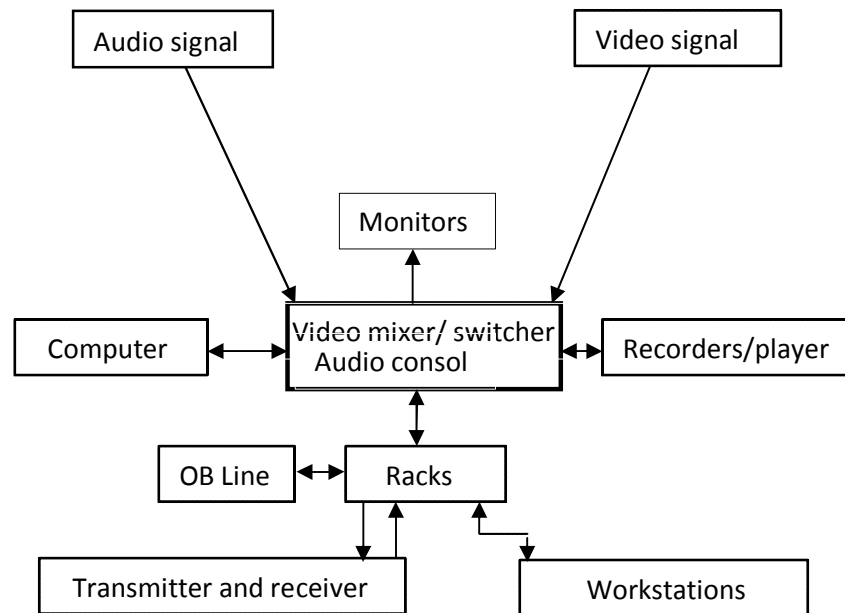


Figure 1.1 Functional block diagram for a typical TV broadcasting studio

The functional block diagram of figure 1.1 explains the physical architecture of the TV broadcasting station of figure 1. The sources of the audio signals from both studios are the sounds, picked up by the microphones which are connected to the audio consol in the control rooms. The sources of the video signals from both studios are the images, captured by the cameras which are linked to the video mixer in the control rooms.

The production control room is equipped with computers for playing, storing, and editing of video and audio programs. Recorders/playback equipment are also used for recording of programs. These programs are previewed by monitors on monitor walls and edited before storage. Master video switchers and audio consol at the master control room are usually used to direct all programs to be aired from station to the transmitter for onward radiation. Audio consol and video mixer/switcher in the production control rooms are used to send programs occurring in the studio to the master video switcher and audio consol to be aired directly. This occurs in stations with more than one studio and studio control room. Network signals can be received from satellite or relayed directly from a program's site. This is linked to the equipment on the rack alongside with signals from outside

broadcasting van(OB Van). A rack is usually a structural metallic stand with provisions for equipment attachment. Productions from the workstations are also connected to the recording equipment mounted on the rack and are available to the master switcher for radiation at the appropriate time. In larger station, all studios are linked to the master control room and are attached to their respective equipment on the racks. More details of the physical architecture of broadcasting station is presented in [13, 14,15, 16, 17] and will be expatiated from other text:

### **2.2.1 The television studio**

Generally, television studios are sound proof rooms uniquely designed to prevent sound disturbances. The studio are suitably furnished and equipped with distributed lighting system for light effect using dimmastats with floodlight. Illumination actually depends on the scene to be televised. The scenes from different angles are telecasted by the camera while the microphone is used to pick up the sounds from different direction. These two categories of signals are transported by coaxial cables to the control rooms where they can be monitored and processed [16]. The pictures of a typical program studio is displayed in figure 1.2 [18]

### **2.2.2 Studio monitors**

Monitors are used in various sections of the studio, studio control room and master control room and they are efficient as monitoring devices for the quality of video signals. Monitors are usually designed not to receive broadcast modulated signals; but as internal devices to check the content of inputs signals at various stages within the broadcast station. Large number of this equipment is usually required to meet the requirement of an efficient broadcast station [19]. Pictures of studio monitors are shown in figure 1.3 (a)

### **2.2.3 Headphones and loudspeakers**

In the studio sound output received from different microphones need to be moderated and regulated to meet broadcast expectations. Headphones and loud speakers are usually used to monitor sound signals [19]. Pictures of headphone and loudspeaker can be seen in figure 1.3 (b) and (c)

### **2.2.4 Studio Microphones.**

Microphones are sound sensitive equipment usually used to pick-up audio at various level of display. The type of microphone and microphone placement activities will actually depend on the type of

program. During drama presentations for instance mikes are usually out of view which can be achieved with the use of hidden microphones or boom-mounted microphones with a boom operator. During discussion, news casting and musical programs microphones are not usually hidden from viewers, mikes can therefore be mounted on floor stands or placed on table stands. [28]. A picture of studio microphone is shown in figure 1.3(d)



Figure 1.2 A production studio. [18]

**Equipment in a studio includes the following;**



**(a)** Studio monitors **(b)** loudspeaker **(c)** headphone **(d)** Studio microphones



Figure 1.3 Studio equipment (a) – (f)

**(e)** High-end professional HDTV

**(f)** Studio camera with an operator.

### **2.2.5 Television camera**

The television camera is an electronic equipment used to capture static and motion images, they are categorized into two; cameras that have what it takes to view scenes and generate a complete television signal, this kind of cameras are usually used for programs that are not located within the studio, and it is accompany with VTR and a small floodlight. Other are high-end camcorders which can record on memory devices such as internal memory, hard drive and memory card and properly edited with a non-linear editing system. [19]. A typical picture of a High-end camcorder can be seen in figure 1.3 (e). The other category is the remote camera which contains photosensitive pick-up-tubes, with its associated deflection circuitry, video preamplifier and a video monitor. This is essentially the one located in the studio. Attached to cameras at the top are view finders, this are monitors made to reproduce the scene on a small picture tube for the operators to see and focus properly. A picture of this categoriesof camera can be seen in figure 1.3 (f) [19]

### **2.3 Studio control rooms (SCR)**

The studio control rooms are usually operated by a program director with an assistant. Video signals are directed by a camera control unit engineer, along with an expert that does the video mixing, and a director for lightning control system. A program director and his crew supervise the program while it is telecasted live, recorded in a VTR, borne directly into a CD or memory card or stored in a computer system.

The studio control room receives signals from different sources such as video and audio transported via coaxial cable linked from the studios and signals from other supplementary sources. A panel could contain video mixer and camera control unit supported by a number of monitors that enable proper preview and editing of outgoing and incoming signal where necessary; depending on the demand of the signals.

The sound engineer controls another similar panel that handles the microphones control and switches linked to associated equipment. The program director also collaborate with both the video unit and sound engineer to control and all available video and sound output.[19] Result from field could also be recorded or relayed through microwave links to the production control room. The picture of a typical studio control room and production control room is shown in figure 1.4 (a)[20]

### **2.3.1 The camera control unit (CCU)**

The camera tube flexibility of beam focus and brightness control, pan-tilt movement is linked to the camera control unit (CCU) for synchronized control. This is achieved by the manipulation of parameter such as video gain, camera sensitivity, blanking level, video polarity etc using various consoles as directed by the producer or using professional experiences and initiatives. A typical example of camera control unit equipment is shown in figure 1.5 (a) [19]

### **2.3.2 Video switcher**

A video switcher is a multi-contact switching machine. It has similar slots for large number of signals inputs and provision for the selection of one or more output that should be linked to an outgoing circuit, the input sources include sources such as signal from camera-1 camera-2é video tape recorders VTR-1, VTR-2é computer system comp-1, comp-2é etc besides test signals and special effect generators. Video signal information from various cameras at various locations can be selected as the need arises or mixed together by the video switcher and as directed by the program director. Video switching machines also have provisions for signal processing such as editing of TV programs. Figure 1.5 (b) represents the picture of a typical professional video mixer. [19]

### **2.3.3 Audio Consol**

The audio console is a sound sensitive input and output switching equipment. Its input is made to blend with a corresponding choice of output channels such that the output channel has provision for the selection of either microphone or sound input line. Echo facilities, and equalizing facilities are usually provided and can be utilized as the needs arises. Examples of audio effect providers are signals from tape recorders and other playback equipments Figure 1.5 (c) shows the picture of a typical audio consol [21]



(a) Studio control room



(b) Production studio control

**Figure 1.4** The control room (a) and (b)

Equipment found in a studio control room includes the following:



(a) Camera control unit equipment



(b) Video mixer



(f) C. D player/Rec.



(c) Audio consol

(d) Computer for editing and storage



(e) Video tape recorder.

**Figure 1.5** Studio control room equipment

### 2.3.4 Master control room (MCR)

The master control room is a central control for all signals from the various studios and production control rooms. It is usually the final switching point that connects the station to its transmitters and when the video and audio sources are not very close to the transmitter plant microwave links are used

as master studio control to transmitter link; also matured outdoor event and programs such as crusades rally, campaign rally and sports are relayed using microwave links. The outside broadcasting van (OB van) is very efficient for this purpose. Centralized video equipment like sync pulse generators, special effect generator test equipment video and audio monitors are usually located in the master control room.

The voltage linked to the transmitter via cable from the control room is raised to about 1-volt-peak to peak when the transmitter is located in the same building. And all unnecessary reduction in signal strength due to cable network is linked to matching network at both ends to balance the signal. [21]. Figure 1.7 is a picture of a typical master control room with work stations.

### 2.3.5 Synchronization pulse generator (SPG)

The sync pulse generator is a device that provides a common station sync, by the use of common deflecting pulses such as sync or blanking pulses so as to keep the deflecting circuit in phase with each other. When there is movement from one camera to another, irregularities of picture appearances could occur. Usually the crystal control sync pulse generator SPG helps to keep scanning in the various camera and monitor in the studio; scanning in the TV receiver and the studio camera as well as other video sources in phase and in perfect synchronism with each other. An example of sync pulse generator is as shown in figure 1.8.(b)

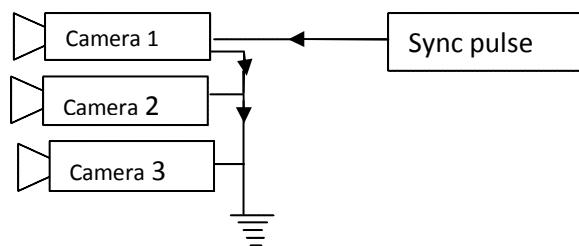


Figure 1.6 The provision of common sync by the sync pulse generator.



**Figure 1.7** Master control room with work stations



**(a)** Equipment racks



**(b)** Sync pulse generators



**(c)** DVD player/Recorder



**(d)** Processors



**(d)** Processors



**(e)** Audio and video distribution amplifiers



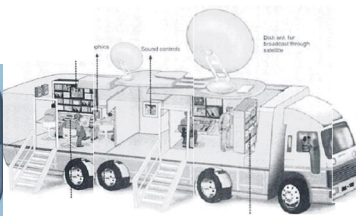
**(f)** Master switcher



**(g)** Antenna



**(h)** Time base corrector TBC



**(i)** OB Van



**(j)** Transmitters



**(k)** Adaptive cable equalizer

**Figure 1.8** Master control room (MCR) equipment

The deflecting pulses provided by the sync pulse generator are; line drive or Horizontal pulses at the rate of 15625Hz, field drive or vertical pulses at the rate of 50Hz, and camera blanking pulses at the H etc

An SPG produces these pulses which are passed through pulse shapers and then distributed to various units through distribution amplifiers [21]. A picture of a typical SPG is shown figure 1.8 (b)

### **2.3.6 Equipment racks**

Equipment rack is usually a metallic structure constructed with attachable slotting and fixing flexibility points. They have provision for the secure mounting of equipment such as CD players, Cassette recorder, Program Switches, etc. Master control rooms for larger stations have equipments that are linked to different equipment rack in various locations of the master control rooms depending on the utilization of the equipments. There are equipment that does not need adjustments such equipments are mounted on rack that are isolated from location where they can be easily tampered with; examples of such equipment are patch jackfields, distribution amplifiers, delegation switchers and amplifiers etc. [22]

The master control room has a usual complex setting of cables connected to the studios and other outside sources with flexible interface points that allows changes such as improvement of cable routing configuration. The equipment rack usually house master distribution frame of cable setting linked to it from the master control room. Other Equipment such as studio transmitter link, audio processor, off-air monitoring receiver, OB lines, additional program source equipment (satellite receivers), digital encoder for satellite uplink, modems, etc are mounted on racks. [22]

### **2.3.7 Time base corrector**

Time base correctors (TBC) are used to create clean video signal with perfect synchronization, video timing and color encoding from an input that may be distorted. It is usually connected between any play back Source. TBC restores and transfers old videos to the recording medium with ideal timing and color information [23]. A picture of a typical time base corrector is shown in figure 1.8 (h)

### **2.3.8 Video and audio distribution amplifier**

Video and audio distribution amplifier allows for a variety of audio and video signal types to be distributed with several outputs for every one input. Each of the video channels are designed with

individual buffers and amplifiers and are sent to various monitors, which means that all output channels are equivalent in terms of signal strength and integrity to the original input signal [24]. A picture of video and audio distribution amplifier is typically represented in figure 1.8 (e)

### **2.3.9 Pulse distribution unit**

The pulse distribution unit is a device that accepts a wide range of input signal levels. Adjustment can be made in the signal to suit the blending of signals for all the attached equipment needing a defined level of pulse trigger output. This adjustment is usually made by an external available selector switch that provides 8 different trigger output [25]

## **2.4 Cable equalizer**

Cable equalizer is a monolithic integrated circuit for equalizing data transmitted over cable or any media with similar dispersive lost characteristics. The equalizer operates over a wide range of data rates from 143 Mbps to 1.485 Gbps [26]. A picture of a typical adoptive cable equalizer is given in figure 1.8 (k)

### **2.4.1 Video tape recorder (VTRs)**

Video tape recorders are appliances for recording video signals. They are made to use high quality video tape facilities examples are two inch tape quadruplet head recording machines which have been standardized, another example is the one or half inch helical scan tape recorders. Video tape recorders are not very stable but require the assistance of time based corrector to be put into the video telecast chain. [27]. The picture of a typical video tape recorder is shown in figure 1.5 (e)

### **2.4.2 Outside broadcasting van (OB VAN)**

The outside broadcasting van can be seen as a portable studio with small control room coupled to FM transmitter and parabolic dish. Most of the equipment that makes up for a successful transmission in a standard transmission station is represented in the OB van. Field events are capture by the cameras and associated microphones linked to the OB van, processed within the OB van and can be transmitted simultaneously through the up-link Fm transmitters to concerned satellite for global relay. A Picture of a typical OB van with internal sectioning is displayed in figure 1.8 (i) [28]

### **2.4.3 Studio to transmitter link**

Standard studios are always associated with a standard control room and master control room as the case might be. Video and audio signals are usually produced in the studio, amplified separately in their control sources using voltage pre-amplifiers and linked to a transmitter. Suitable locations for transmitter installations are on towers and hills which may not be good site for artist and studio function. However signals can be transported to transmitters either through the broadband coaxial

cable, optical fiber or microwave links depending on its proximity to the studio. [28]. Pictures of typical antenna tower and transmitters are displayed in figure 1.8 (g) and (j) respectively.

## **2.5 TV signal broadcasting**

The sensation of motion is transmitted to the viewer by a successive display of still picture frame at a regular rate. Fifty frames per second corresponding to 50Hz power line frequency of NTA for its adopted PAL system is used to scan for one frame twice in 64 micro seconds [29]. This scanning traces the pixels (dots forming an image) for the 625 lines each picture frame is divided into and converts its color intensity and/or variation into electrical signal which is processed and radiated. Our home TV receiver intercepts the signal and reverses the process to reproduce the exact image and audio. This process is very interesting but only reliable if the equipment involved is reliable. [29]

## **2.6 Reliability of component in broadcast station subsystem**

To ascertain the efficiency of broadcast equipment the concept of reliability is needed. Reliability is the ability of a system of component to perform its required function under stated condition for a given period of time. [30]

In the exponential distribution failure rate assumption may not be valid but is widely used in reliability and maintainability study at system level. At component level the exponential distribution is limited because it is not able to analyze in detail the constituent of the system and therefore deals mainly on regular plain of maintenance and replacement [31]

The right approach at component level is the use of a method of analysis of component called the physics of failure based on other statistical model such as Logman or Weibull distribution. Although the reliability of all the component that makes up a system to a great extent determine the reliability of the entire system. The system reliability can still be assessed based on regular maintenance and replacement of parts.

Considering the reliability of a system based on the reliability of its composition two methods are usually used to make reliability estimations; the part count method and the part stress analysis method.

The part count method places little or no priority on quantity of different part. Quality level of the various parts and the environments where operations takes place. When the system is tested at the early design phase bid/proposal formulation this method can be used.

The part stress method has a different approach it stresses on greater details in order to analyze the system this method find appropriate application usually during latter design phase.

The assumption in the part count application is that the broadcast system will fail if any of its part fails hence can be expressed as;

$$\lambda = \sum_{i=1}^n \lambda_i \quad (1)$$

Where:

$\lambda_i$  = failure rate of the  $i^{th}$  part and

n = number of part.

The part count is also based on (i) generic part type including (including complexities of micro - electronics) and quantities(ii) part quality level and (iii) equipment environment conditions

The expression of equation one is the analysis of the system when the entire equipment is from the same environment.

Sometimes the system may be made up of several unit operating in different environment, for each of the units and its peculiar environment , the general expression for equipment failure rate for a given environment is stated in equation (2).

$$\lambda = \sum_{i=1}^N \lambda_i (\lambda_i \lambda_i) \quad (2)$$

Where:

$\lambda$  = Constant equipment failure rate

$\lambda_i$  = Generic failure rate for the  $i^{th}$  generic part (failure/10h)

$\lambda_i$  = The quality factor for the  $i^{th}$  generic part

$\lambda_i$  = Quantity for the  $i^{th}$  generic part

N= number of different generic part categories

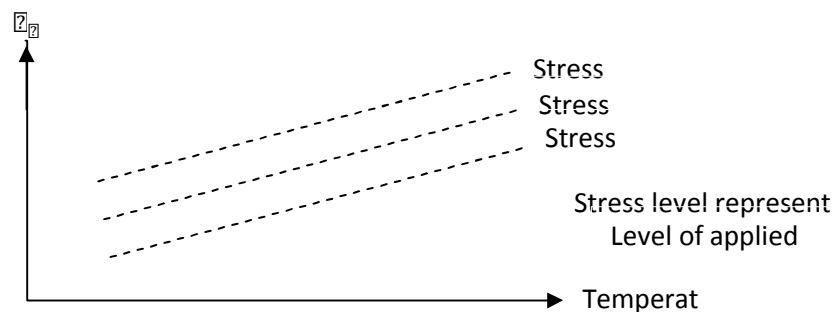


**Figure 1.9** Part based failure rate versus stress and temperature

From the graph it can be deduced that as the temperature increases the stress on the equipment also increases resulting to increasing failure rate, but the stress level is patterned into levels such that the reliability of the equipment based on the stress level is ascertained.

Considering the part stress method the part failure method of analytical representation varies with different part types, but their general form is as stated in equation (3)

$$\lambda_T = \lambda_0 \lambda_1 \lambda_2 \lambda_3 \lambda_4 \lambda_5 \lambda_6 \dots \dots \lambda_n \quad (3)$$

Where:

$\lambda_0$  = Base failure rate

$\lambda_1$  = Environmental adjustment factor: this is based on the environmental influence and the stress it induces on the part apart from the temperature (vibration, humidity, etc)

$\lambda_2$  = Adjustment factor; this factor considers the way or rate at which the part of an entire system is being used, in fact it largely depends on the manufacturing style and control

A graphical representation of the part stress method will involve data relating failure rate to normalized stress and the associated reaction to temperature factor.

Therefore when design is to take place with the appropriate reliability in question design control will be based on the values of applied stress in relative to the rated stress.[32]

**Related works on system reliability along with other relevant literatures are presented as follows:**

## 2.7. Effects of variation in the reliability of series components

When constituents of a system are connected such that failure of any of the component results to the failure of the system it is connected in series. Series system reliability configuration of equipment can be calculated by the product of each of the reliability of the equipments that make up the system.

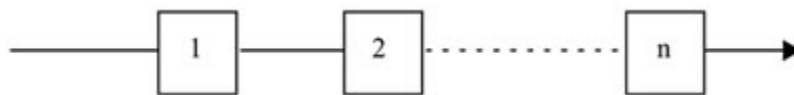


Figure 2. series configuration

It is usually expressed as stated in equation (6) [37]

$$R_{sys} = \prod_{i=1}^n R_i \quad (6)$$

Where:

$R_{sys}$  = Reliability of the system

$R_i$  = Reliability of the subsystem equipment that makes up the system.

Therefore  $R_{sys} = R_1 \times R_2 \times R_3 \dots R_n$

The reliability of a system with serial configuration of equipment is equal to the product of the reliability of the equipment that makes up the system. It is usually expressed as stated in equation (6)

$$R_{sys} = \prod_{i=1}^n R_i \quad (6)$$

Where:

$R_{sys}$  = Reliability of the system

$R_i$  = Reliability of the subsystem equipment that makes up the system.

Series systems changes sensitively with subsystem having very low reliability (subsystem with the least reliability value). Table 1 table one

**Table 1: The effect of change in reliability of a series system**

|            | $R_1$      | $R_2$      | $R_3$      | System $R_{sys}$ |
|------------|------------|------------|------------|------------------|
| <b>I</b>   | <b>0.5</b> | <b>0.6</b> | <b>0.7</b> | <b>0.210</b>     |
| <b>II</b>  | <b>0.6</b> | <b>0.6</b> | <b>0.7</b> | <b>0.252</b>     |
| <b>III</b> | <b>0.5</b> | <b>0.7</b> | <b>0.7</b> | <b>0.245</b>     |
| <b>IV</b>  | <b>0.5</b> | <b>0.6</b> | <b>0.8</b> | <b>0.240</b>     |

Table one above explains the sensitivity of series system to part of the system with the least reliability value. Taking the reliability of three components  $R_1$ ,  $R_2$ ,  $R_3$  to be 0.5, 0.6, 0.7.

The reliability of the system at stage **I** without any increment is 0.210. The reliability of the system at each of the other stages **I**, **II**, **III** **IV** can be evaluated as shown;

$R_1$  has reliability that increased by 10% in the second stage the corresponding system reliability value is 0.252 which is 20% increment in the reliability of the system and it is the component with the least reliability value. Increasing  $R_2$  by 10% in the third stage results to system reliability value of 0.245 which is about 16.7% increase in the reliability of the system. Similarly increasing  $R_3$  by 10% in the fourth stage only resulted to about 14% increase in the reliability of the system indicating that the component with the least reliability value affects the system the most.

### 2.7.1 Effect of the number of subsystems on the reliability of series system

The number of equipment connected together serially affects the system to a great degree, the greater the number of subsystem component, the lower the system reliability. Figure 2.1 shows that as reliability increases from 10% to 99% the system reliability does not increase commensurately but tend to increase slowly as the number of component increases. In fact, the more the number of component in series the lower the reliability value of the system as shown in figure 2.1`

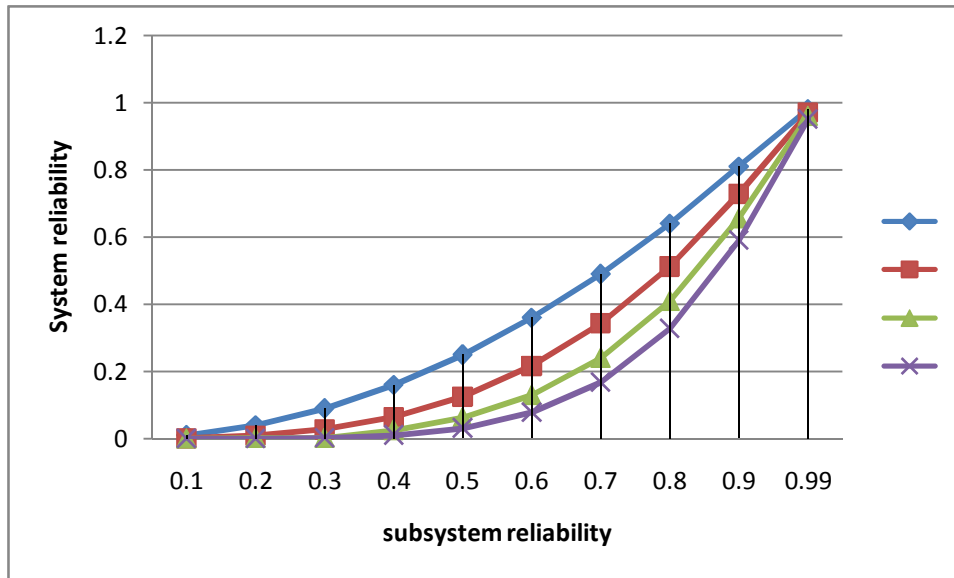
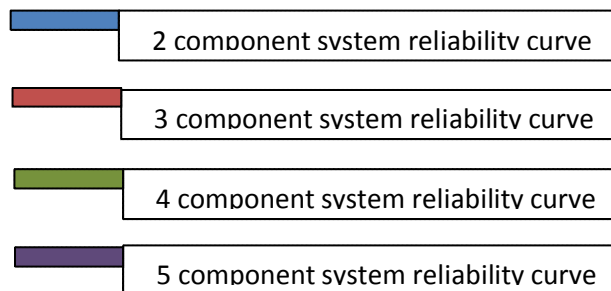


**Figure 2.1** The reliability of a series system ( $F_s$ ) with  $n$  equipment.

Each color of the graph stated above is a representation of the number of component that makes up for the characteristics of the reliability of the system.



### 2.7.2 Effects of components' reliability variation of a parallel system

In parallel system the failure of a subsystem does not lead to the failure of the entire system. parallel system reliability configuration can be expressed as stated in equation (7)[33]

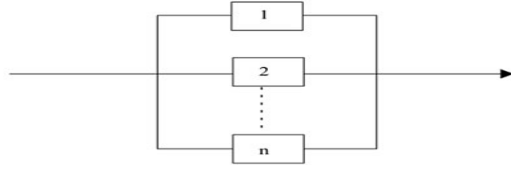


Figure 2.2 A block diagram model for a parallel system [34]

$$R_{sys} = 1 - \prod_{i=1}^n (1 - R_i) \quad (7)$$

Where;

$R_{sys}$  = reliability of the parallel system

$R_i$  = subsystem reliability

$$R_i = 1 - (1 - R_1) - (1 - R_2) - (1 - R_3) - \dots - (1 - R_n) \quad [34]$$

Considering a system with three subsystems equipment, equation  $R_{sys}$ ,  $R_i$  in parallel with reliabilities  $R_{sys} = 94\%$ ,  $R_{sys} = 95\%$ ,  $R_{sys} = 95.5\%$  represented in three stages of the table 2

**Table 1: The effect of change in reliability of a parallel system**

|            | $R_{sys}$  | $R_{sys}$  | $R_{sys}$  | System $R_{sys}$ |
|------------|------------|------------|------------|------------------|
| <b>I</b>   | <b>0.5</b> | <b>0.6</b> | <b>0.7</b> | <b>0.940</b>     |
| <b>II</b>  | <b>0.6</b> | <b>0.6</b> | <b>0.7</b> | <b>0.950</b>     |
| <b>III</b> | <b>0.5</b> | <b>0.7</b> | <b>0.7</b> | <b>0.955</b>     |
| <b>IV</b>  | <b>0.5</b> | <b>0.6</b> | <b>0.8</b> | <b>0.960</b>     |

The first stage has the reliability of each component and the corresponding reliability value of the system. In the first stage the reliability of the system is 0.940 or 94%. In the second stage  $R_{sys}$  is increased by 10% the reliability of the system is 0.950 which increases the system reliability by 1.28%. The third stage also has  $R_{sys}$  increased by 10%, the reliability of the system is 0.955 which

increases the system's reliability by about 1.59%, similarly, the fourth stage increased the system reliability by about 2%. This implies that increasing the reliability of the highest subsystem improves the reliability of the system the most, although increments are very small in the parallel system.

### 2.7.3 Effect of the number of subsystems on the reliability of parallel system

In parallel subsystem increasing the number of subsystem reliability will also increase the reliability of the entire system irrespective of the reliability value, although increasing the reliability of the equipment with the highest reliability value will suffice the more in the reliability of the entire system. From figure 2.2 the curves formed from the characteristic of the parallel system seems to be directly opposite of the series reliability curves. Hence the colors are reversed from the highest to the lowest according to the extent at which the reliability of the entire system is improved; [33]

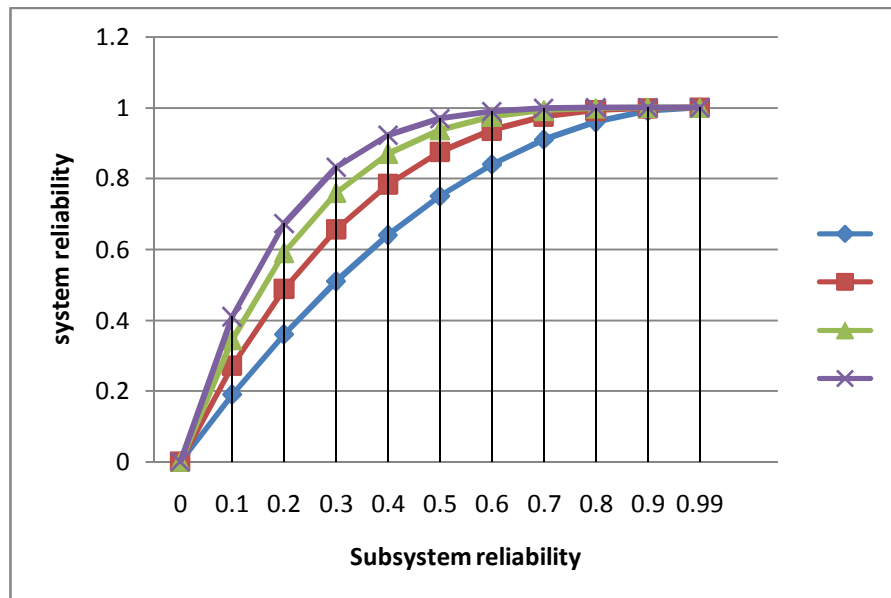
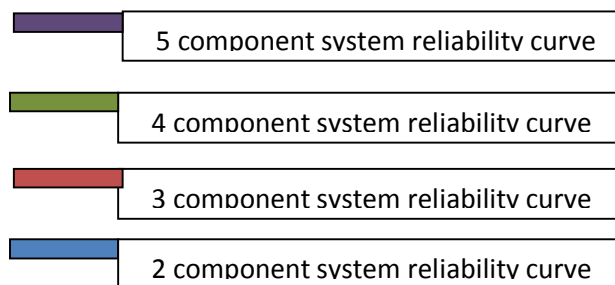


Figure 2.3 The reliability of a parallel system with n equipment



### 2.7.4 Reliability block diagram

Reliability is a success oriented network describing a function of a system. The diagram has one source A and one terminal B each block represents the function of a component or subsystem, if the function is available we have connection through the block. If we have connections between A and B it means the system is functioning. Reliability block diagram only represent the function of a system. Two different system functions will have two reliability block diagram [34].

### 2.7.5 k-out-of-n Parallel System: F-redundancy

A system can be made of subsystem such that at least two subsystem functions out of N subsystems connected in parallel. Subsystems are independent and identical with the same failure distribution. In this case when one subsystem fails as long as at least any other two subsystem is functioning the system does not fail. The reliability of such a configuration can be evaluated by binomial distribution and can be expressed as stated in equation 9[34]

$$R_s(k, n, R) = \sum_{r=k}^n \binom{n}{r} R^r (1 - R)^{n-r} \quad (9)$$

Where:

$n$  = the total number of units in parallel.

$r$  = the number that must function properly for system success

$k$  = the minimum number of units required for system success.

$R$  = the reliability of each unit.

A block diagram model for a k-out-of-n Parallel system is represented in figure 1.3

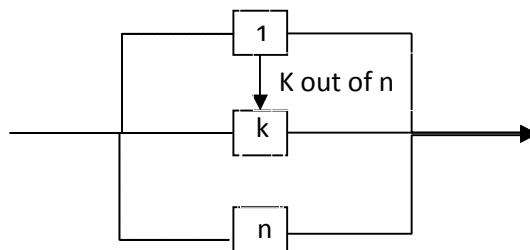


Figure 2.4 A block diagram model for k-out-of-n Parallel System: F-redundancy [34].

## 2.8 Failure rate

Equipment with time is bound to fail. The frequency of failure per unit time can be seen as its failure rate or failure rate can be defined as the number of failure per unit time. It is connected to the Mean time between failures [MTBF] as expressed in equation (11).

$$\lambda = \frac{1}{\text{MTBF}} \quad (11)$$

Where:

MTBF = The average time a unit operates between failures

The observed mean time between failures is the mean value of the length of time between consecutive failures computed as the ratio of the running hours to total number of failures [35]. MTBF is usually expressed practically as stated in equation (12)

$$\text{MTBF} = \frac{\text{Total running hours}}{\text{Total number of failures}} \quad (12)$$

### 2.8.1 Maintainability

Equipment and installation needs to be retained in continuous satisfactory operating condition, according to prescribed procedure and resources. This is done within a given time when maintenance action is performed. The time to restore probability density function is given as

$$P(t) = P_0 e^{-\lambda t} = \frac{P_0}{\lambda t} = P_0 \frac{1}{\lambda t} \quad (13)$$

Where:

$\lambda$  = equipment corrective repair replacement or restoration rate, in restoration per unit time e.g restoration per hour.

$t$  = is the time to correctively repair replace of restore the equipment to satisfactory function.

MTTR = mean time required to correctively repair replace or restore the equipment to satisfactory function expressed in the same time unit as  $t$ . [35]

### 2.8.2 Restoration rate

Maintenance actions are usually carried out in a work place to keep equipment functional especially when it fails to perform the desired work. The number of maintenance or restoration action performed and successfully completed per unit time (1h) is called restoration rate. The restoration rate for exponential distribution is expressed as stated in equation (14)

$$R = \frac{\sum_{i=1}^N \lambda_i \bar{r}_i}{\sum_{i=1}^N \lambda_i} \quad (14)$$

Where:

$N$  = total number of repairable or replaceable component

$\lambda_i$  = Failure rate of the  $i$ th component in failure per unit time or

$\bar{r}_i$  = Mean equipment repair time when the  $i$ th component fails

The restoration rate can therefore be expressed as stated in equation (16)

$$R = \frac{R}{\lambda} \quad (16). [35]$$

### 2.8.3 Exponential distribution

Electronic equipment are made with a special internal characteristics of operation. Its reliability is predictable almost exclusively by the exponential model of reliability analysis. The exponential model is very useful and simple to understand with a constant hazard rate and it is a special case of weibull distribution when  $\beta = 1$  (useful life period of an equipment) at this point ( $\beta$ ) it has a constant failure rate with normal operating hours.[36] Other categorization of equipment as shown in figure 2.5 include two more failure rate situation. Many manufactured equipment are often defected; this could be as a result of the materials used in their manufacturing or when they are being conveyed to customers' destination. In most cases the associated hazard, tend to decrease with time as the equipment approaches its useful period. This is called the infant mortality failures. Here  $\beta < 1$ [3]

The third characterization of the bathtub curve is the last section of the curve called the wear out period. At this stage the equipment have exhausted their useful life and are beginning to fail more rapidly. This is a case of weibull distribution when  $\beta > 1$  to help this situation system can be

improved open by carrying out the preventive maintenance which may sometimes include replacement of parts on order to revive the usefulness of the material.

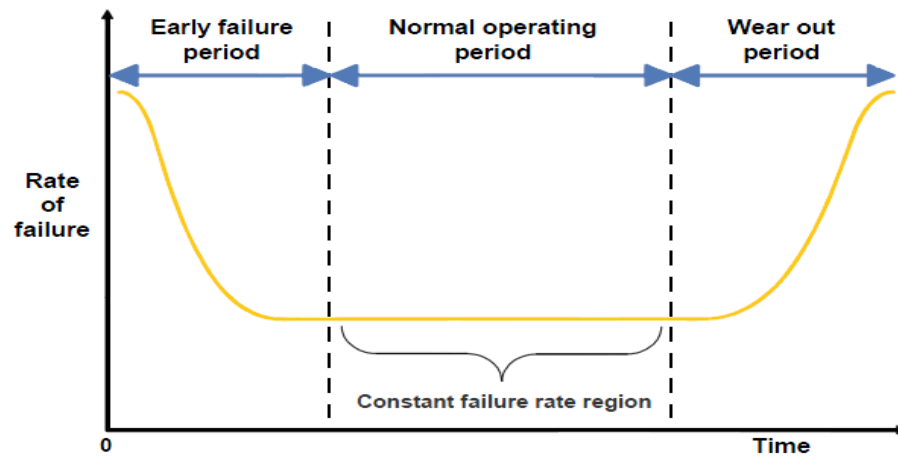


Figure 2.5 Reliability bathtub curve [36]

## **CHAPTER THREE**

### **DEVELOPMENT OF RELIABILITY MODEL**

#### **3.1 Introduction**

In order to represent real life situation or state mathematically logically or mechanically there is need to establish a typical relationship, theory, process, system or sequence of event, this representation is called a model. It summarizes the complex situation of real world or it functions as a way of illustrating a theory. Analytical modeling is an equation or set of equation used to describe the performance of a system[37]

In this chapter therefore, Jos TV broadcasting studio equipment configuration will be presented. A model of the study that is based on equipment's configuration will be derived.

#### **3.2 Jos TV broadcasting studio equipment configuration**

This aspect of the research is based on the functional block diagram of studio equipment configuration taken from the NTA Jos broadcast setting. Studio broadcasting equipment is usually configured with a setting that enables review and optimization as technology improves and communication demands increases. Changes with trends of technology can be very rapid there is therefore need for a flexible interface that helps the station to improve in the application of technology.

This research applies proper view of reliability configuration using the functional block diagram. Since its reliability configuration analysis serves as an example of establishing a methodological strategy, the configuration of other broadcast station can be evaluated in similar manner. This proposes better ways of improving the settings for other configuration such as:

- Making sure that every subsystem has an active redundant subsystem in order to reduce the influence of failures.
- Investigating and ensuring high reliability for any single equipment in series within the system especially when redundancy is very expensive to apply.

### 3.3 Nigeria Television Authority Jos



**Figure 3.1** Nigerian Television Authority Jos (NTA JOS)

The JosTV broadcasting studio is equipped with facilities for TV transmission. This is the station whose reliability is assessed in this research work.



(a) Transmitter 1



(b) Transmitter 2



(c) A Section of the program studio



(d) Workstations



(e) News broadcasting studio



(f) Program  
Control room



(g) Master control  
room

**Figure 3.2** Sections of the NTA Jos broadcasting station

The researchers' choice of design from the NTA Jos is based on the fact that the Nigerian television collage where staff of NTA nationwide are been trained is near in proximity to it. Trainees can easily see and practice in NTA Jos, what they have learnt when the facilities at the college is inadequate. The first color television in West Africa was first implemented there, which gives a good impression about their prompt response to improvement in technology

NTA Jos technical section comprises of the maintenance rooms attached to the work station (d), transmitters (a, b), News broadcasting studio (e), program studio (c), production control room (f), and Master control room (g). The control for the news broadcasting studio is also located in the master control room. It has four work stations for editing and production purposes made to meet demands of the customers. The picture of NTA Jos broadcasting station and the main sections of the broadcasting studio is as shown in figure 3.1 and 3.2.

### **3.4 Modeling procedure/steps:**

The modeling steps are illustrated using the flow chart [figure 3.3]

**Step (1):** Development of broadcasting studio's functional block diagram for the equipment in the Jos broadcasting station

**Step (2):** Specification of time sensitive conditions for failures peculiar to the station.

**Step (3):** Identification of the failures of each subsystem in the broadcasting station with respect to their effect on the failure of the entire system.

**Step (4):** Categorization of all equipment into series and parallel reliability connection based on subsystem failures identified in step (3) above and their configuration.

**Step (5):** Development of the reliability models

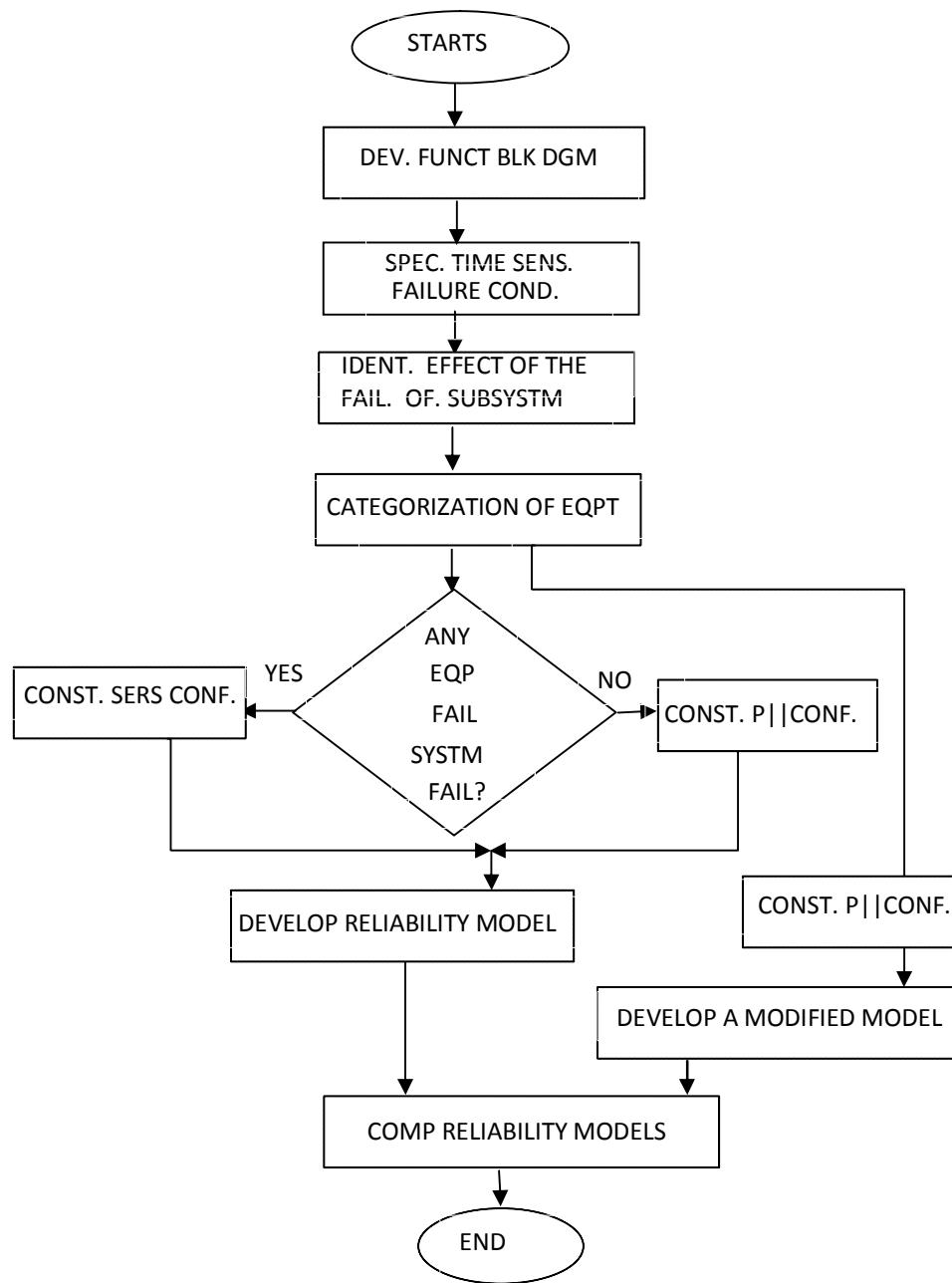


**Figure 3.3A** Chart for the modeling procedure

The flow chart above explains the strategy expressed in the procedure/steps. Some of the expression indicated in the flow chart and what they denote is as shown below:

- DEV. FUNCT BLK DGM → Develop the functional block diagram.
- SPEC TIME SENS. FAIL COND → Specification of time sensitive failure condition.
- IDENT. EFFECT OF FAIL. OF SUBSYSTEM → Identification of the failure of each subsystem

- CATEGORIZATION OF EQT → categorization of equipment into series and parallel connections.
- ANY EQP FAIL SYSTM FAIL? → If any equipment fails does the system fail?
- CONST. SERS CONF → Construction of series configuration for equipments of the system in series
- CONST. P|| CONF → Construction of Parallel configuration for equipments of the system in parallel.
- DEVELOPRELIABILITY MODEL → The combination of the series and parallel configuration and development of analytical model.
- DEVELOP RELIABILITY MODEL 2 → Reconfiguration to obtain a complete series system of parallel subsystem from the first configuration.
- VALIDATE RELIABILITY MODEL → Compare and validate reliability model

The modeling procedure involved developing a functional block diagram for the Jos broadcasting station after which time sensitive failure condition was specified. The failures of each subsystem in the broadcasting station with respect to their effect on the failure of the entire system are then identified. This led to the categorization of equipment into series and parallel reliability connection.

All equipment whose failure results to the failure of the entire system was arranged in series configuration. Equipment whose failure does not lead to the failure of the entire system as a result of active redundant subsystem was arranged as parallel configuration. These two categories of equipment were linked together so that the system could be modeled analytically. The resultant analytical reliability model was compared with another expression of a modified model. The modified model is the reconstruction of the configuration of the model such that: each of its subsystem has parallel configuration.

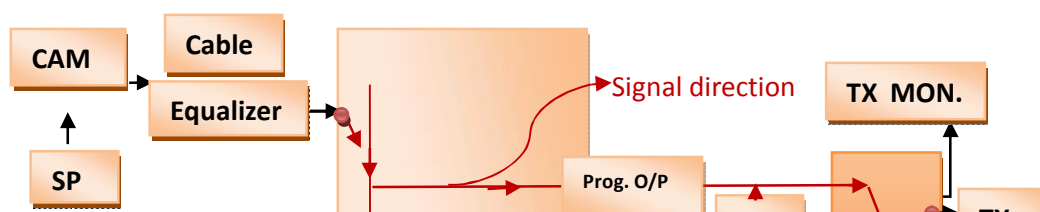
### 3.4.1 Jos television broadcasting studio (video line)

Considering the functional block diagram of the TV broadcast studio shown in figure 3.4, one can see the various studio signal sources. Studio sources include the camera, professional VHS recording/playback machine. The DVD machines also for play backs/recordings, the VCR machines, character generator, the down-link satellite receiver with source input from the satellite dishes (through the LNBs) and other sources are shown in figure 3.4.

These sources are channeled to the master video matrix/video switcher where all the transmission channel switching is done. A remote control or keyboard section is provided, where the transmission controller sits down to do the sources switching. An array of monitors which displays the pictures from the various picture sources is placed in front of the transmission controller.

The transmission controller views the sources to be transmitted on the preview monitor and presses the preview output button, to ensure that the output is perfect and finally uses the transmission button to take the program on air. The transmission output passes through the time based corrector to correct for any error that may not be totally eradicated in all the total time of the video. The output of the time based corrector is taken to the transmission video distribution amplifier (VDA) where it is distributed to the area that requires it, such areas includes: transmitters, recording studios, key areas in the engineering control room, administrative offices and maintenance rooms.

### 3.4.2 Functional block diagram of Jos television broadcasting studio



**Step 2, Specification of failure condition**

The specification of failure condition is dependent on how long the reliability of the system is to be accessed. NTA Jos operates for a period of about 18 hours during the day and was initiated with a standard of failure free operation. The station permits few seconds of change over for different power source. When there is a long time break in transmission or there may be prolonged make-and-break the station is said to have failed.

**Step 3, Identification of the failures of each subsystem in the broadcasting station with respect to their effect on the failure of the entire system.**

Looking at the functional block diagram of figure 3.4 the following classification ensues:

**Power supply:**

- The power supply is most essential, without which the broadcasting studio is completely cut off. The power supply PHCN is connected in series, but for continuity, generators are used as alternative, Therefore the two sources are in parallel to each other, with result  $\square_{\square}$  in series with the system  $\square_{\square}$ .

**Signal sources:** The signal sources are of numerous Alternatives:

- The Cameras (CAM) are in parallel, connected in series with their cable equalizers (C.EQ) because when one camera is not working the other is a suitable alternative. The result is in parallel with video cassette recorder VCR because event recorded can be an alternative source. The result is in series with sync pulse generator to prevent distorted output because it provides a reference sink for the output this forms  $\square_{\square\square}$
- The digital versatile disc DVD1 and DVD2, satellite receivers SAT1 and SAT2, stored and edited video/advert from computer (ON COMP), recorded program from outside broadcasting Van (OB VAN) in series with cable equalizer (C.EQ), are all connected in parallel as shown in  $\square_{\square\square}$  of figure 3.5 because they are all alternative sources of signal to the entire system. All of the above forms the entire column  $\square_{\square}$ .
- **Switching/ processing stages**
- There is no alternative for the video Matrix/production switcher  $\square_{\square}$  if it fails the system fails therefore it is connected in series to the system  $\square_{\square}$ .
- The time base corrector TBC has no alternative if it fails the system fails, it is also connected in series as  $\square_{\square}$  with the system  $\square_{\square}$

- The transmission video distribution amplifier also have no alternative to switch to, it is also connected in series as  $2_{27}$  with the system  $2_{27}$
- The transmitters are two and are therefore in parallel, with result  $2_{27}$  connected in series with the system  $2_{27}$

**Step (4), Categorization of all equipment into series and parallel reliability connection based on subsystem failures identified in step (3) above and their configuration.**

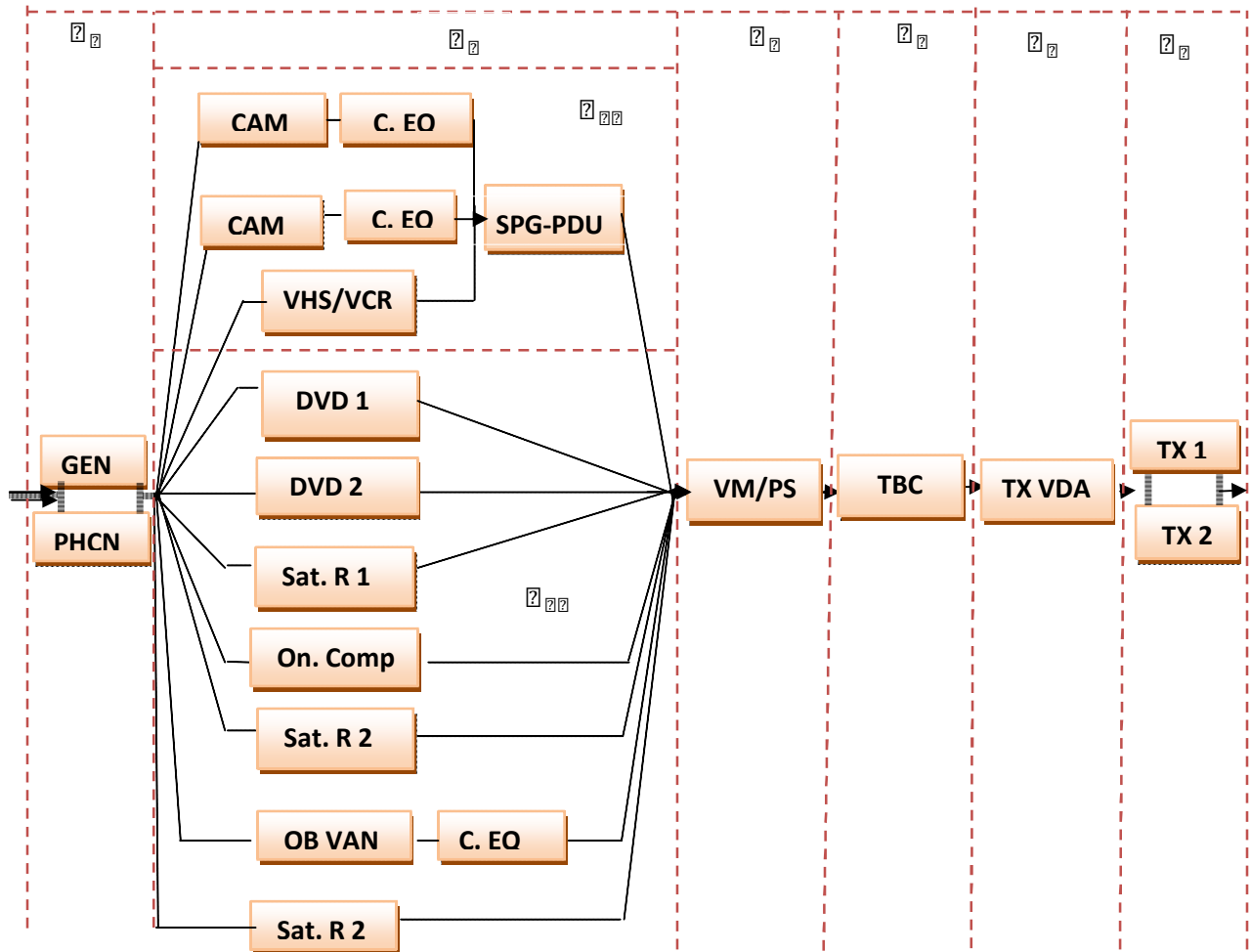


**Figure 3.5** Reliability configurations for the Functional block diagram of Jos television broadcasting studio (video line)

**Step (5) Development of the reliability model**

### 3.4.3 Analytical modeling

The power supply of figure 3.4 is connected in parallel as shown in equation (1.1).

$$R_{Sub1} = R_{P, supply} = 1 - (1 - R_{GEN}) \times (1 - R_{PHCN}) \quad (1.1)$$

The two cameras are connected in series with their cable equalizers as  $R_{CAM1} \times R_{C, EQ}$  and  $R_{CAM2} \times R_{C, EQ}$ , Such that  $R_{CAM1} \times R_{C, EQ}$ ,  $R_{CAM2} \times R_{C, EQ}$  and  $R_{VCR}$  are all in parallel but their combination is in series with  $R_{SPG}$  therefore the expression for the reliability of the subsystem  $R_{21}$  is given as:

$$R_{21} = [1 - (1 - R_{CAM1} \times R_{C, EQ}) \times (1 - R_{CAM2} \times R_{C, EQ}) \times (1 - R_{VCR})] \times R_{SPG}$$

The resultant is in parallel with the parallel combinations in  $R_{22}$  of figure 3.5 such as  $R_{DVD1}$ ,  $R_{DVD2}$ ,  $R_{SAT1}$ ,  $R_{COMP}$ , and  $R_{SAT2}$ . The outside broadcasting van is connected in series with cable equalizer as  $R_{OB, VAN} \times R_{C, EQ}$

The resultant of the parallel combinations  $R_{21}$  and  $R_{22}$  is as expressed as stated in equation (1.2)

$$R_2 = \{1 - [(1 - (1 - R_{CAM1} \times R_{C, EQ}) \times (1 - R_{CAM2} \times R_{C, EQ}) \times (1 - R_{VTR/VCR})) \times R_{SPG}]] \times (1 - R_{DVD1}) \times (1 - R_{DVD2}) \times (1 - R_{SAT, R1}) \times (1 - R_{COMP}) \times (1 - R_{SAT, R2}) \times (1 - R_{OB, VAN} \times R_{C, EQ}) \times (1 - R_{C, G})\} \quad (1.2)$$

This is combined with the series configuration of master video switcher/ production matrix (VM/PS) of equation (1.3)

$$R_3 = R_{VM/PS} \quad (1.3)$$

Time based corrector (TBC) of equation (1.4) is also connected in series

$$R_4 = R_{TBC} \quad (1.4)$$

This is also in series with transmission video distribution amplifier (TX.VDA) of equation (1.5)

$$R_5 = R_{TX, VDA} \quad (1.5)$$

And finally, two transmitters (TX) are connected in parallel as shown in equation (1.6)

$$R_{Sub6} = 1 - (1 - R_{TX1}) \times (1 - R_{TX2}) \quad (1.6)$$

Combining equations (1.1) to (1.6) the expression for the reliability of the whole video section is obtained as stated in equation (1.7)

$$\begin{aligned}
 R_{\text{System}} = & [1-(1-R_{\text{GEN}}) \times (1-R_{\text{PHCN}})] \times \{1-[[1-(1 \dot{\bar{R}}_{\text{CAM1}} R_{\text{C.EQ}}) \times (1 \dot{\bar{R}}_{\text{CAM2}} R_{\text{C.EQ}}) \\
 & \times (1 \dot{\bar{R}}_{\text{VCR}})] \times R_{\text{SPG}}] \times (1 \dot{\bar{R}}_{\text{DVD1}}) \times (1 \dot{\bar{R}}_{\text{DVD2}}) \times (1 \dot{\bar{R}}_{\text{SAT.R1}}) \times (1 \dot{\bar{R}}_{\text{COMP}}) \times \\
 & (1 \dot{\bar{R}}_{\text{SAT.R2}}) \times (1 \dot{\bar{R}}_{\text{OBVAN}} R_{\text{C.EQ}}) \times (1 \dot{\bar{R}}_{\text{C.G}})]\} \times R_{\text{VM/PS}} \times R_{\text{TBC}} \times R_{\text{TX VDA}} \times \\
 & [1-(1 \dot{\bar{R}}_{\text{TX1}}) \times (1 \dot{\bar{R}}_{\text{TX2}})]
 \end{aligned} \tag{1.7}$$

### 3.4.4 Jos television broadcasting studio (audio line)

The audio from all studio sources are taken to audio high level amplifier where they are amplified to their required levels, after which they are taken separately to the network, the particular output that is for transmission is switched on through the audio switcher's key board and routed to the transmission audio distribution amplifier (ADA), where they are distributed to the sources that require them i.e. to receiver studio and to studio amplifier. Figure 3.6 is a typical block diagram of the audio line of the broadcasting studio.

#### Step (1), Development of broadcasting station's functional block diagram for the equipment in the Jos broadcasting studio

Jos broadcasting studio have audio connections distributed round the studio, maintenance rooms and administrative offices, figure 3.6 is a typical block diagram representation of the audio section.

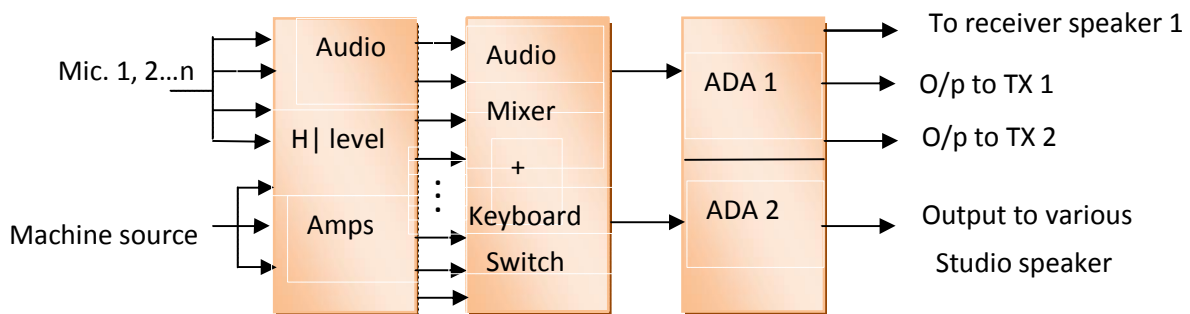


**Figure 3.6** Functional block diagram of Jos television broadcasting studio (audio line)

**Step 2, Specification of failure condition:** The failure condition for the audio line is the same as that of the video line.

**Step 3, Identification of the failures of each subsystem in the broadcasting station with respect to their effect on the failure of the entire system.**

**Power supply:**

- The video and the audio have the same source of power supply. The power supply PHCN is connected in series, but for reliability sake generator is used as alternative, Therefore the two sources are in parallel to each other, with result  $\bar{P}_1$  in series with the system  $\bar{P}_1$ .

**Switch:**

- The audio mixer (AUD MIX) have no alternative if it fails the system fails, therefore it is connected in series  $\bar{P}_1$  to the system  $\bar{P}_1$

**Audio sources**

- There are four microphone ( $\bar{P}_1$ ,  $\bar{P}_1$ ,  $\bar{P}_1$ ,  $\bar{P}_1$ ) and three machine sources  $\bar{P}_1$ ,  $\bar{P}_1$ ,  $\bar{P}_1$  and they are all connected in parallel as  $\bar{P}_1$  to the system  $\bar{P}_1$

**Processing**

- The amplifier (P.AMP), and audio distribution amplifier (ADA) are single mode without alternatives resulting to series connectivity  $\bar{P}_1$  and  $\bar{P}_1$  respectively
- Then finally the transmitter connection is the same as that of the video line and they are in parallel because there is available alternative if any one fails the other takes over.

**Step (4), Categorization of all equipment into series and parallel reliability connection based on subsystem failures identified in step (3) above and their configuration.**

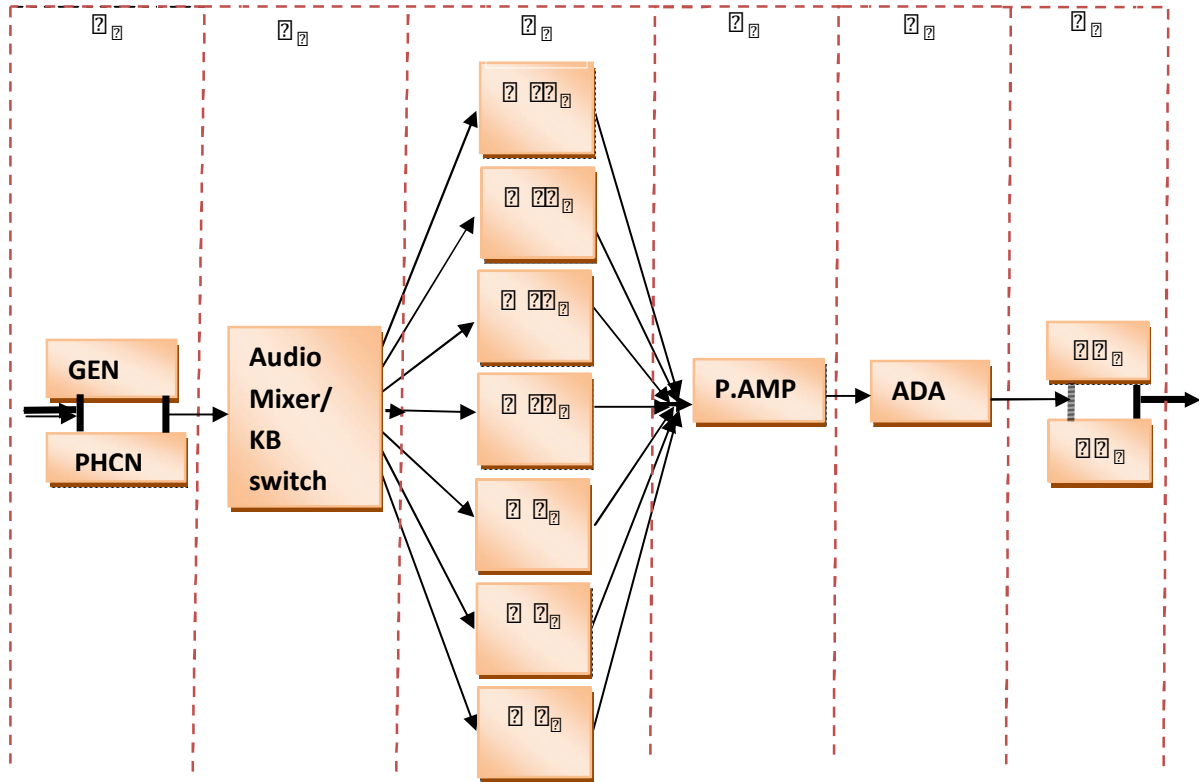


**Figure 3.7** Reliability configuration for the functional block diagram of a television broadcasting studio (Audio line).

### Step (5) Development of the reliability model

The power supply is the generator and power holding company connected in parallel as stated in equation (1.8)

$$R_{PS} = 1 - (1 - R_{GEN}) - (1 - R_{PHCN}) \quad (1.8)$$

The result of the power supply is in series with the audio mixer/keyboard switch of equation (1.9) (AUD.MIX/KBS)

$$R_{PS} = R_{PS} \cdot R_{AUD.MIX/KBS} \quad (1.9)$$

Four Microphones (MIC) and two Machines for audio sources are connected in parallel as stated in equation (2.1).

$$R_{MIC} = 1 - (1 - R_{MIC1}) - (1 - R_{MIC2}) - (1 - R_{MIC3}) - (1 - R_{MIC4}) - (1 - R_{MIC5}) - (1 - R_{MIC6})$$



$$(1 - R_{C.G}) \} \times R_{VM/PS} \times R_{TBC} \times R_{TX} \times R_{VDA} \times [1 - (1 - R_{TX1}) \times (1 - R_{TX2})] \times \{ 1 - R_{11} - R_{12} - R_{13} - R_{14} - R_{15} - R_{16} - R_{17} - R_{18} - R_{19} - R_{20} - R_{21} - R_{22} - R_{23} - R_{24} - R_{25} - R_{26} - R_{27} - R_{28} - R_{29} - R_{30} - R_{31} - R_{32} - R_{33} - R_{34} - R_{35} - R_{36} - R_{37} - R_{38} - R_{39} - R_{40} - R_{41} - R_{42} - R_{43} - R_{44} - R_{45} - R_{46} - R_{47} - R_{48} - R_{49} - R_{50} - R_{51} - R_{52} - R_{53} - R_{54} - R_{55} - R_{56} - R_{57} - R_{58} - R_{59} - R_{60} - R_{61} - R_{62} - R_{63} - R_{64} - R_{65} - R_{66} - R_{67} - R_{68} - R_{69} - R_{70} - R_{71} - R_{72} - R_{73} - R_{74} - R_{75} - R_{76} - R_{77} - R_{78} - R_{79} - R_{80} - R_{81} - R_{82} - R_{83} - R_{84} - R_{85} - R_{86} - R_{87} - R_{88} - R_{89} - R_{90} - R_{91} - R_{92} - R_{93} - R_{94} - R_{95} - R_{96} - R_{97} - R_{98} - R_{99} - R_{100} \} (2.7)$$

The above expression of equation (2.7) is the combination of six major subsystems each of both parallel and series connection of the audio and video line of figures 3.5 and 3.7.

$$R_S = R_{Sub1} \times R_{Sub2} \times R_{Sub3} \times R_{Sub4} \times R_{Sub5} \times R_{Sub6}$$

The reliability of electronic equipments such as the broadcasting equipment is expressed as stated in equation (2.8)

$$R = e^{-\lambda T} (2.8)$$

Where:

$\lambda$  = Failure rate of the system

T = mission period

The failure rate of the system can then be relayed as stated in equation (2.9):

$$\lambda = \frac{\sum_{i=1}^N \lambda_i}{N} (2.9)$$

The restoration rate is given from maintainability engineering as expressed in equation (3.0)

$$\mu = \frac{\sum_{i=1}^N \mu_i}{N} (3.0)$$

Where  $i = 1, 2, 3 \dots n$

N = total number of repairable or replaceable equipment

T = mission time.

$\mu_i$  = mean time to repair when the  $i$ th component fail.

$\lambda_i$  = Failure rate of the  $i$ th equipment in failures per unit time.

$$\lambda_i = \frac{\lambda}{N} (3.1)$$



alternative, Therefore the two sources are in parallel to each other, with result  $\Sigma$  in series with the system  $\Sigma$ .

**Signal sources:** The signal sources are of numerous Alternatives:

- The Cameras (CAM) are in parallel, connected in series with their cable equalizers (C.EQ) because when one camera is not working the other is a suitable alternative. The result is in parallel to video cassette recorder VCR because event recorded can be an alternative source. The result is in series with sync pulse generator to prevent distorted output because it provides a reference sink for the output this forms  $\Sigma$
- The digital versatile disc DVD1 and DVD2, satellite receivers SAT1 and SAT2, stored and edited video/advert from computer (ON COMP), recorded program from outside broadcasting Van (OB VAN) in series with cable equalizer (C.EQ), are all connected in parallel  $\Sigma$  because they are all alternative sources of signal to the entire system. All of the above forms the entire column  $\Sigma$ .

#### Switching/processing stages

- The video Matrix/production switcher of ( $\Sigma$ ) is connected to a suitable alternative such that if it fails the system has a standby subsystem therefore it is connected in parallel to each other and in series with the system  $\Sigma$ .
- The time base corrector TBC of  $\Sigma$  is connected to a suitable alternative such that if it fails the system has a standby subsystem therefore it is connected in parallel to each other and in series with the system  $\Sigma$ .
- The transmission video distribution amplifier (TXVDA) of  $\Sigma$  has also an alternative to switch to, it is also connected in parallel to each other and in series with the system as with the system  $\Sigma$
- The transmitters are two and are therefore in parallel, with result  $\Sigma$  connected in series with the system  $\Sigma$

**Step (4), Categorization of all equipment into series and parallel reliability connection based on subsystem failures identified in step (3) above and their configuration.**

For the sake of comparison, the video equipment of a complete series system of parallel subsystem was analyzed in similar way and the result is shown in figure 3.8.

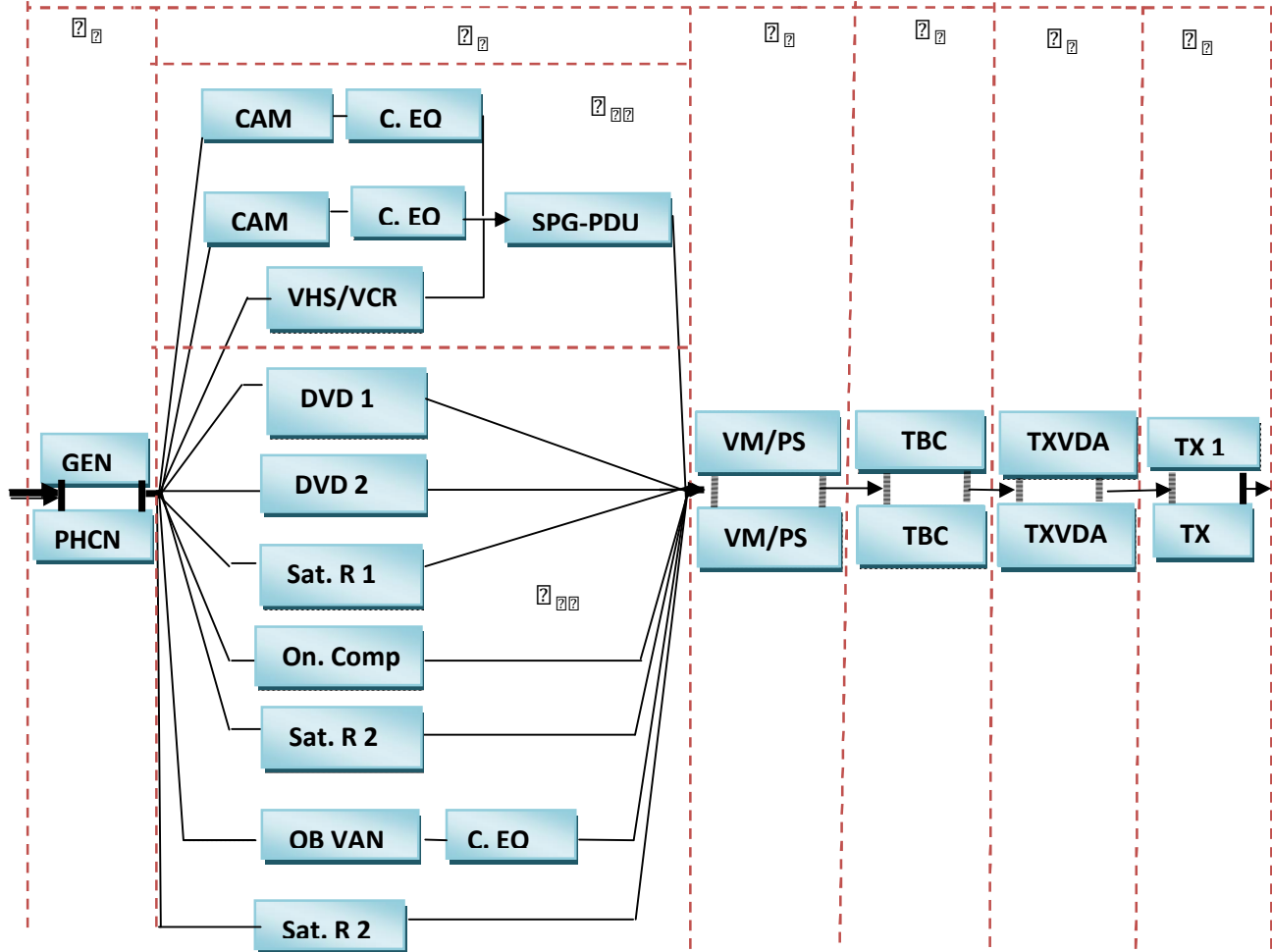


**Figure 3.8** Configuration for the modified model (video line)

#### Step (5) Development of the reliability models

The method of development of the reliability model in the modified model is the similar to that of model. The reliability of the video line of equipment of figure 3.8 is given as expressed in equation (4.3)

$$R_{System} = [1 - (1 - R_{GEN}) \times (1 - R_{PHCN})] \times \{1 - [(1 - (1 - R_{CAM1} \times R_{C.EQ}) \times (1 - R_{CAM2} \times R_{C.EQ}) \times (1 - R_{VCR})) \times R_{SPG}] \times (1 - R_{DVD1}) \times (1 - R_{DVD2}) \times (1 - R_{SAT.R1}) \times (1 - R_{COMP}) \times$$

$$(1 - R_{SAT,R2}) \times (1 - R_{OBVAN} R_{C.EQ}) \times (1 - R_{C.G}) \times [1 - (1 - R_{VM/PS}) \times (1 - R_{VM/PS})] \times [1 - (1 - R_{TBC}) \times (1 - R_{TBC})] \times [1 - (1 - R_{TXVDA}) \times (1 - R_{TXVDA})] \times [1 - (1 - R_{TX1}) \times (1 - R_{TX2})] \quad (4.3)$$

### 3.5.1 The modified model (audio line)

The audio line of the modified model was analyzed in similar way. The first and second procedures/steps are the same with that of the first model.

**Step (3): Identification of the failures of each subsystem in the broadcasting station with respect to their effect on the failure of the entire system.**

**Power supply:**

- The video and the audio have the same source of power supply. The power supply PHCN is connected in series, but for reliability sake generator is used as alternative, Therefore the two sources are in parallel to each other, with result  $R_{PS}$  in series with the system  $R_{S}$ .

**Switch:**

- The audio mixer (AUD MIX) have suitable alternative if it fail the standby subsystem serves the station therefore it is connected in parallel to each other  $R_{S}$  but in series with the system  $R_{S}$

**Audio sources**

- There are four microphone ( $R_{M1}, R_{M2}, R_{M3}, R_{M4}$ ) and three machine sources  $R_{M5}, R_{M6}, R_{M7}$  and they are all connected in parallel as  $R_{S}$  to each other and in series with the system  $R_{S}$

**Processing**

- The amplifier (P.AMP), and audio distribution amplifier (ADA) have subsystem resulting to parallel configuration as  $R_{S}$  and  $R_{S}$  of figure 3.9 respectively.
- Then finally the transmitter connection is the same as that of the video line and they are in parallel because there is available alternative if any one fails the other takes over.

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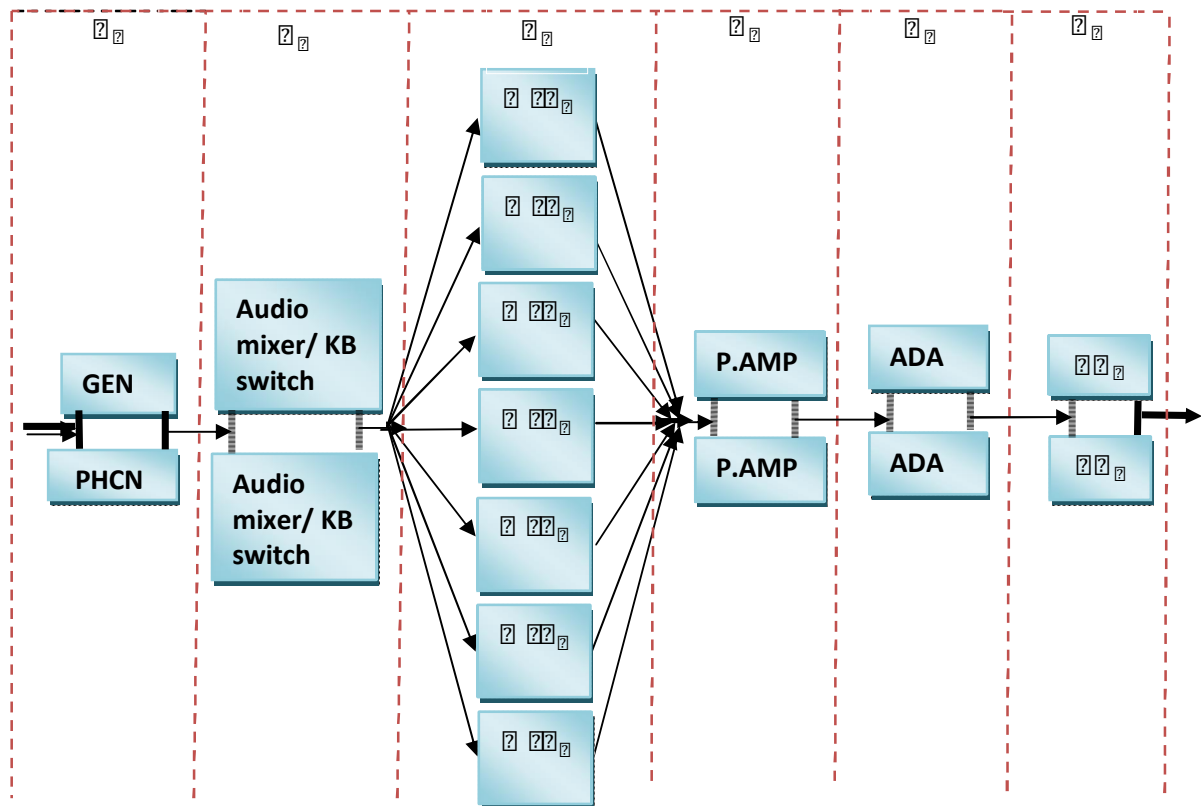


**Figure 3.9** Configuration for the modified model (Audio line).

### Step (5) Development of the reliability model (audio line)

The method for the derivation of the reliability expression for model two is the same with that of model one.

$$\begin{aligned} \mathbb{Q}^2 = & \mathbb{Q}^1 - \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \\ & \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^2 [1 - \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1] \mathbb{Q}^2 [1 - \\ & \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2 \mathbb{Q}^1 - \mathbb{Q}_{\mathbb{Q}^2 \mathbb{Q}^2}^2 \mathbb{Q}^2] (5.0) \end{aligned}$$

The reliability of power source and the transmitter have been evaluated in the video line of equipment.

### 3.5.2 The equation for the modified model



element of the adopted series represents the sum of repair time for the subsystem equipment of the station in a year.

## **CHAPTER FOUR**

### **RESULTS AND RESULT ANALYSIS**

#### **4.1 Introduction**

The results of this research work were presented analytically and graphically. The preceding chapter showed how the model summarized the analysis of the reliability configuration of Jos broadcasting studio. This chapter in addition, presents the reliability of NTA Jos broadcasting studio together with the effects of short time reliability assessment of the models of the systems.

The model simulation involves charts and graphical comparison and analysis of the behaviors of the models. Data were used to evaluate the behaviors of each model with respect to increments in the reliability of their subsystem.

#### **4.2 Practical reliability parameters.**

NTA Jos operates for 18 hours in a day and 6570 hours in a year. The technical department of the station assessed the equipment and ascertained their running hours and failure mode. The mean time between failures (MTBF) was evaluated as the ratio of the running hours to the number of failures. The associated failure rate of the equipment was the inverse of the mean time between failures. This information were inferred from the daily duty and operations recorded in a log book.

#### **4.3 Exclusions of the study**

The reliability of the broadcasting station was evaluated from the combination of subsystem equipment that is directly involved in the transmission process. Obviously, the broadcasting process cannot be very effective without the minor monitoring, testing and troubleshooting equipment. In order to prevent false impression of the reliability of the station the minor equipments must be excluded: since they are not directly involved in the TV signal broadcasting of the station. The failure of such equipment even during the broadcasting period does not affect the signal. The technical crew simply replaces them while the transmission is still taking place.

Table of values and the evaluation of the reliability of equipment based on the information acquired from the technical team are tabulated as table 3. The respective reliability of all the equipment and sources that are directly linked with the signal during broadcasting is highlighted in the table.

**TABLE 3.** Data from the NTA Jos broadcasting studio

| S/<br>N | EQUIPMENT                           | AVERAGE<br>RUNNING<br>HOURS | NoOF<br>FAILURE<br>(y times) | MTBF<br>$\frac{2022}{202022}$ | FAILURE<br>RATE | REL.<br>FOR ONE<br>YR (%) |
|---------|-------------------------------------|-----------------------------|------------------------------|-------------------------------|-----------------|---------------------------|
| 1       | Generator                           | 3,024                       | 1                            | 3024                          | 0.00033069      | 11.14                     |
| 2       | PHCN                                | 126                         | 8                            | 15.75                         | 0.06349206      | Very small                |
| 3       | VCR                                 | 1512                        | 1                            | 1512                          | 0.00066137      | 1.297                     |
| 4       | Cable equalizer C.EQ                | 6,048                       | 1                            | 6048                          | 0.00016534      | 33.74                     |
| 5       | Camera                              | 6,048                       | 2                            | 3024                          | 0.00033069      | 11.14                     |
| 6       | DVD                                 | 3,024                       | 1                            | 3024                          | 0.00033069      | 11.14                     |
| 7       | Video mixer /switcher.<br>PS/VM     | 42,336                      | 1                            | 42,336                        | 0.00002361      | 85.6                      |
| 8       | Time based corrector<br>TBC         | 12,098                      | 1                            | 12098                         | 0.00008266      | 58.1                      |
| 9       | Audio Microphone                    | 1,512                       | 1                            | 1512                          | 0.00066137      | 1.297                     |
| 10      | High level amplifier P.<br>AMP      | 12,098                      | 1                            | 12098                         | 0.00008266      | 58.1                      |
| 11      | Satellite receiver                  | 12,098                      | 1                            | 12098                         | 0.00008266      | 58.1                      |
| 12      | Audio mixer/switcher                | 21,160                      | 1                            | 21,160                        | 0.00004726      | 73.3                      |
| 13      | Audio distribution<br>amplifier ADA | 12,098                      | 1                            | 12,098                        | 0.00008266      | 58.1                      |
| 14      | Character generator                 | 42,336                      | 1                            | 42,336                        | 0.00002362      | 85.6                      |
| 15      | Online computer                     | 12,098                      | 1                            | 12098                         | 0.00008266      | 58.1                      |
| 16      | Audio Machine (MS)                  | 6,048                       | 1                            | 6048                          | 0.00016534      | 33.7                      |
| 17      | Sync pulse generator                | 12,098                      | 1                            | 12098                         | 0.00008266      | 58.1                      |
| 18      | Video distribution<br>amplifier VDA | 12,098                      | 1                            | 12,098                        | 0.00008266      | 58.1                      |
| 19      | Transmitters                        | 6,048                       | 1                            | 6,048                         | 0.00016534      | 33.7                      |



A homogeneous failure rate of  $\lambda$  per unit of time  $t$  which constitutes reliability over a period  $T$  is used to display the nature of failure free period. The reliability of the station can be evaluated from the reliability specifications of table 3; for each of the equipment reliability expressed in table 3 and using the analytical reliability model of equation (2.7) the reliability of the Jos broadcasting studio for a period of one year was evaluated and given as:

$$R_M = 0.0033 \text{ or}$$

$$R_M = 0.33\%$$

Using equation (5.3), the number of hours the station will have to operate between failures is evaluated as follows:

$$0.33 = \frac{1}{\lambda} \left( \frac{1}{T} \right)^{\lambda}$$

$$\lambda = 1149.8 \text{ (Approximately 2 month, 7 days of failure free hours of operation)}$$

Based on table 1 and on a homogeneous failure rate that resulted to 0.33 percent reliability of the NTA Jos reliability model, the station is to fail only after 1149.8 hours of failure free operation. The failure rate can be evaluated using equation (2.9), which is restated as:

$$\lambda = \frac{1 - R_M}{T}$$

The failure rate of Jos broadcasting station (NTA Jos) reliability model using equation (2.9) is given as 0.0001687 units per hour.

The configuration of the model was reconstructed to form the modified model of parallel subsystems which was the expression of equation (5.2). The reliability from the modified model was evaluated and given as:

$$R_{MM} = 0.0137 \text{ or}$$

$$R_{MM} = 1.37\%$$

Using equation (5.3), the number of hours the station will have to operate between failures is evaluated as follows:

$$0.0137 = \frac{1}{\lambda} \left( \frac{1}{T} \right)^{\lambda}$$

$$\theta = 1,531 \text{ hours (approximately 3 month 1 days of failure free hours of operation)}$$

Also based on the data in table 1 and for a homogeneous failure rate that resulted to 1.37 percent reliability, with the improved situation of the model, the system is to fail once every 1,531 hours. Using the failure rate expression of equation (2.9), the failure rate of the modified model is given as 0.000653 units per hour.

The model of the broadcasting studio expresses the fact that the vulnerability of the station to sudden signal failure is once every 1149.8 hours. The vulnerability of the modified model to sudden signal failure was evaluated to be once every 1,531 hours: a difference of 382 hours with reliability disparity of 1.04%. This indicates that subsystem redundancy is very important if the reliability of the station must be improved upon.

#### 4.5 Short time reliability assessment

When reliability assessment of equipment is done for a shorter time (mission time T), the reliability of the model is always higher. Considering the equipment reliability listed in table 3, the running hours of most of the equipment is higher than a month. If the model of the system were to be considered for a time shorter than the running hours of subsystems, system reliability will be very high.

##### 4.5.1 One week reliability assessment

Based on the values of equipment reliability specified in table 3, and the expression of equation (2.7) the reliability of the Jos broadcasting studio was evaluated for a week (126 hours) which resulted to:

$$R_M = 0.901 \text{ or}$$

$$R_M = 90\% \text{ in percentage}$$

Using equation (5.3), the number of hours the station will have to operate between failures is evaluated as follows:

$$0.901 = e^{-\frac{\theta}{T}} \dots$$

$$\theta = 1,208.6 \text{ hours. (67 days or 2 month, 11 days)}$$

Based on the table 3, and on a homogeneous failure rate that resulted to 90 percent reliability of the NTA Jos reliability model, the station is likely to fail ones every 1,208.6hours. This result implies that the state of the broadcasting studio is far better than just a one week reliability assessment: it will not fail at all throughout the week. Using equation (2.9), the failure rate of Jos broadcasting studio (NTA Jos) for a period of one week is given as 0.000827units per hour.

#### 4.5.2 One month reliability assessment

Based on the values of equipment reliability specified in table 3, and the expression of equation (2.7) the reliability of the Jos broadcasting studio was evaluated for a month (504hours) which resulted to:

$$R_M = 0.686 \text{ or}$$

$$R_M = 68.6\%$$

Using equation (5.3), the number of hours the station will have to operate before a single failure is evaluated as follows:

$$0.686 = \frac{1}{1 + \frac{1}{0.686}} \dots$$

$$\frac{1}{1 + \frac{1}{0.686}} = 1,337.3 \text{ hours. (74.3 days or 4 month, 2.3 days)}$$

Based on the table 3, and on a homogeneous failure rate that resulted to 68.6 percent reliability of the NTA Jos reliability model, the broadcasting studio is likely to fail ones every 1,337.3hours. This result implies that the state of the broadcasting studio is better than just a one month of reliability assessment: it will not fail at all throughout the month. The failure rate of Jos broadcasting studio (NTA Jos) using equation (2.9) in this case is given as 0.0007478units per hour.

#### 4.6 Model simulation

The model simulation was made by reconfiguring Jos broadcasting studio equipment configuration and its analysis which is the model of the studio in order to form a modified model of a near ideal condition. The modified model is then used to qualify the behavior of the model in order to ascertain its inadequacy. The weakness associated with the modified model as shown in this research is that: when two subsystems are connected in parallel and both have very low reliability, they will complement each other too often. Persistent failure of this nature also reduces the reliability of the entire system.

Misfortunes of persistent failure exhibited by paired devices can be avoided when more equipment are connected in parallel to each subsystem. This makes the modified model to approach ideal condition; ideal conditions of this nature are not realistic because broadcasting equipment can be very expensive. That is why the modified system only modeled an applicable configuration: It added just one active redundancy to every single series subsystem.

The models were simulated using various parameter of evaluation such as: operational behavior, reliability, failure rate and restoration rate of the models of the system with respect to their subsystems' reliability. The behavior of the model is then analyzed from the behavior of the modified model because of the advantage of modified model over the model originating from the configuration of the station.

#### 4.6.1 Operational behavior of the models

The reliability of NTA Jos was actually low; it is amazing to see such a low reliability giving the associated number of operating hours. This can be explained from the characteristic of a bar chart that shows the inclination of the model for a year (6570hrs) with respect to hours of operation before the likelihood of failure. Equation (5.3) shows that the reliability can also be expressed as:

$$R = \frac{1}{1 + \frac{y}{x}} \text{ When } y = 1$$

The number of hours of operation (x) between failures is therefore given as expressed in equation (5.4)

$$x = \frac{1}{R - 1} \quad (5.4)$$

#### 4.7 The model

With a homogeneous failure rate of reliabilities that ranges from 10% to 90% the bar charts of figure 4.0 exemplifies the hours of failures of each model with respect to changes in the reliability of their subsystems.

The bar chart of figure 4.0 shows that for a one year reliability assessment, the model represented in equation (2.7) shows a behavior that increases as reliability increases. At 10% reliability of all subsystem on a level ground, the station is expected to experience a failure free period of 356 hours

after which there is likelihood of failure. At 20% reliability of all subsystem, there was an increment of 184hours resulting to 540hours between failures.

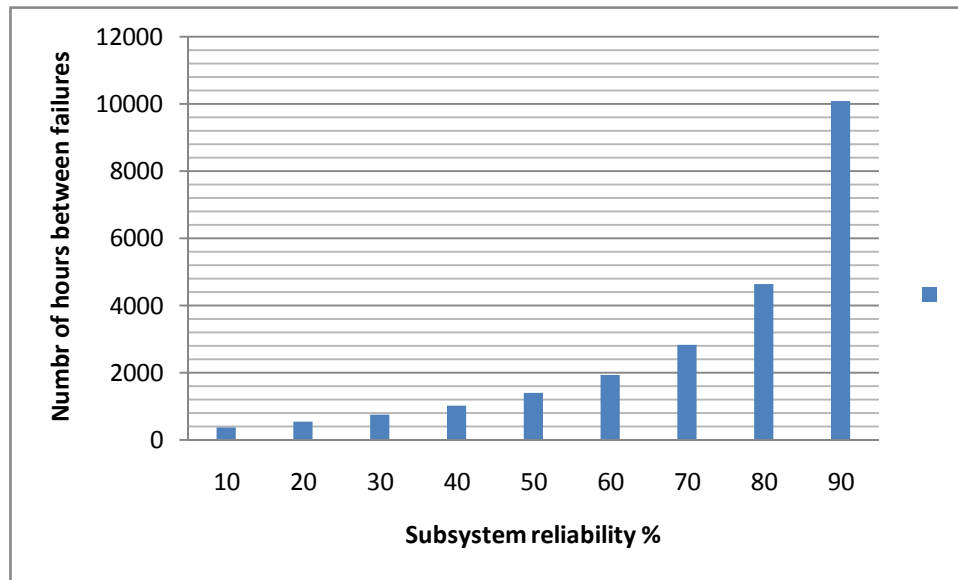


**Figure 4.0** Bar Chart of running hours versus subsystem reliability (model of the station)

The incremental trend of hours between failures for 40%, 50%, 60% and 70% reliabilities of the associated subsystem were 1018,1383,1922 and 2820hours of the system respectively as shown in figure 4. This is an indication of the fact that the responds of the model to increasing reliability of subsystem is obvious. At 70% the increment was close to double of the previous.

This analysis vindicates the reality of the reliability of the station evaluated previously. The reliability from the model evaluation resulted to 0.33% with failure free period of 1,149.8 hours (63.8days of operation). This is possible because even at 10% reliability of all subsystem the reliability of the model was  $9.8 \times 10^{-7}\%$  which resulted to 356 failure free hours (more than 19 days of operation). At 50% reliability of subsystems the reliability of the station was 0.863% which resulted to 1,383 hours between failures(76 days of operation).

At 99% reliability of the subsystems the reliability of the station is 94 % which resulted to 108,586 failure free hours (6032 days or 16 years of operation). The bar chart of figure 4.0 shows subsystem reliability on the horizontal axis. The actual value of each bar with respect to the associated system is shown in figure 4.1. One can observe from the graph that the system's reliability only began to rise significantly at 50% subsystem reliability (1,383system's failure free hours), more of the behavior of this model is shown in the graph of figure 4.1. The model from the configuration of the NTA Jos

needed to be modified, if at 99% reliability of the associated subsystem, the system failure free period is just 16years. Bearing in mind the fact that, such healthy state of subsystem may not be attainable on a continuous base.

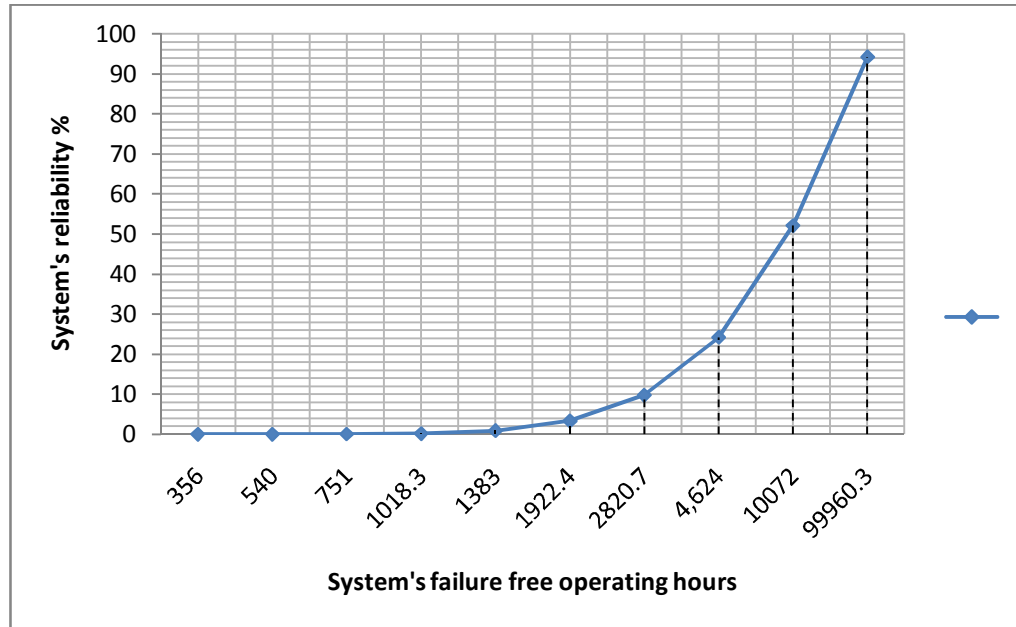


**Figure 4.1** Graph of system's reliability and system's failure free operating hours

#### 4.7.1 The modified model

One can also examine the modified model representing the series system of parallel subsystem configuration shown in figure 4.2. At 10% reliability of all subsystem on a level ground, a station with such configuration is expected to experience a failure free period of 388.9 hours after which there is likelihood of failure. At 20% reliability, there was an increment of 370.6 hours resulting to 759.5 hours between failures. At 30% reliability, there was an increment of 421 hours resulting to 1180.5 hours between failures.

At 40%, 50%, 60% and 70% reliabilities they were increments of 6285, 1023, 1864.4, and 4004 hours between failures respectively. This is an indication of the greater extent at which the modified model responded to changes in its subsystem. At 80%, and 90% reliability of all subsystem, the hour between failures incremented by 11,414 hours and 61,598 hours resulting to 20,115 and 81,713 running hours between failures.

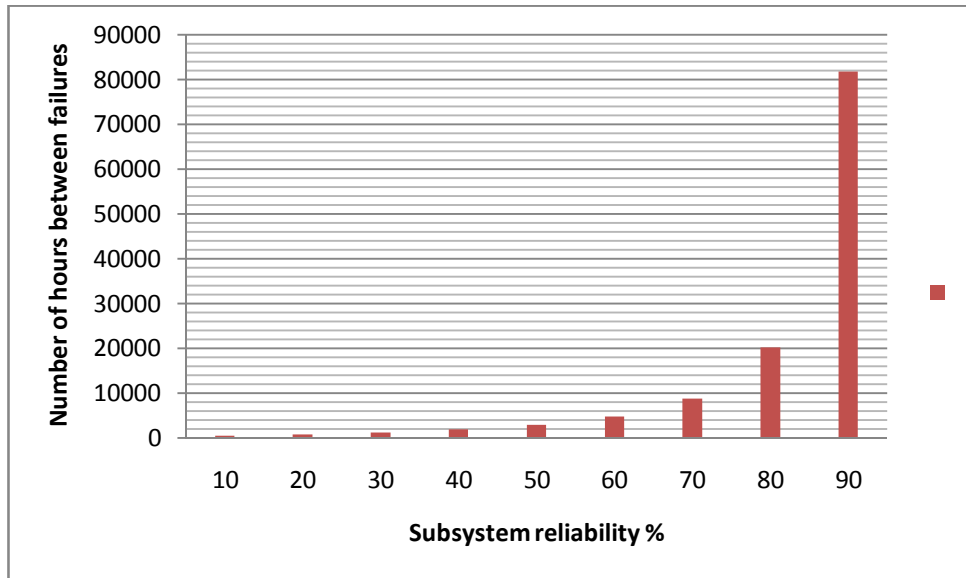


**Figure 4.2** Bar Chart of running hours versus subsystem reliability (modified model)

The exponential behavior of the modified model heightened to an alarming difference from 80% to 90%. It means at 90% reliability of subsystem the modified model will approximately gain 9.4 years of failure free hours on the associated down time than when it had 80% subsystem reliability. The 99% subsystem reliability resulted to 8,212,089 failure free hours; this is out of scale for the chart of figure 4.2, because the difference is much. This means the modified model responded more positively to increment in the reliability of its subsystem than the model of the broadcasting studio. This is an indication of an optimized system with failure free period increasing more rapidly as reliability increases.

This analysis vindicates the reality of the reliability of the station evaluated previously. The reliability from the modified model evaluation resulted to 1.37% with failure free period of 1,531 hours (85 days failure free operation). This is also possible because at 10% reliability of all subsystem the reliability of the modified model was  $4.6 \times 10^{-6}\%$  which resulted to 388.9 failure free hours (22 failure free days of operation). At 50% reliability of subsystems the reliability of the modified model is 9.8% which resulted to 2,832.6 hours between failures (157 days or 5 months of operation).

At 99% reliability of subsystems, the reliability of the modified model is 99.9% which finally resulted to 8,212,089 failure free period (456,227.2 days or 1,249 years of operation), this is the ultimate goal: the modified model has a system that will never fail, even for many decades. More of the behavior of the modified model of the system is seen in the graph of figure 4.3; it shows that at

40% subsystem reliability (1,809 system's failure free hours) the curve began to rise significantly. The system responds faster to changes in subsystem reliability.

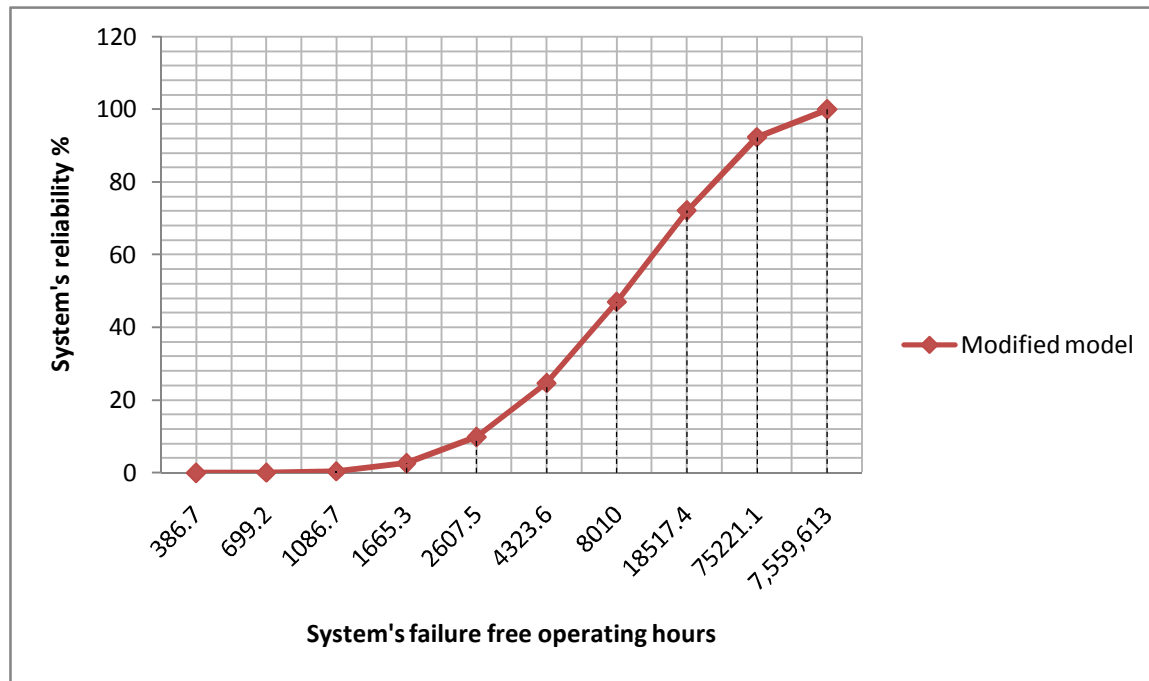


**Figure 4.3** Graph of system's reliability and system's failure free operating hours

#### 4.8 Comparison of behavior

The modified model responded more rapidly to changes in the reliability of its subsystem. At 10% subsystem reliability the modified model will operate for 388.9 hours with 33 extra hours above the model from the broadcasting studio. Similarly, the differences between the models at 20%, 40%, 60% and 90% subsystem reliabilities were 219.5, 791, 2774.6 and 71,641 operating hours of the system respectively in favor of the modified model; this can be seen from figures 4.1 and 4.3. These differences are very large even as subsystem reliability approaches 90% and above; this explains the importance of subsystem redundancy. The horizontal axis can also represent successive subsystem reliability represented as shown in figures 4 and 4.1

The graphs of figures 4.1 and 4.3 also emphasize the importance of subsystem redundancy. One can observe that at 99% the modified model will operate for 8,212,089 failure free hours (1,249.93 years)

as oppose to the 16.5 years of operation of the model directly representing the reliability of the station.

#### 4.8.1 Reliability of models and subsystems' reliability analysis

The reliability of the models resulting from the reliability of their respective subsystem is graphical illustrated in figure 4.4. In order to evaluate the models of the systems, subsystem's reliability was taken from 10% to 99%. The corresponding system reliability was evaluated and plotted against subsystem reliability as shown in figure 4.4. The distinctiveness at each point was clearly stated so that the advantage of employing a series system with parallel subsystem can be clearly shown.

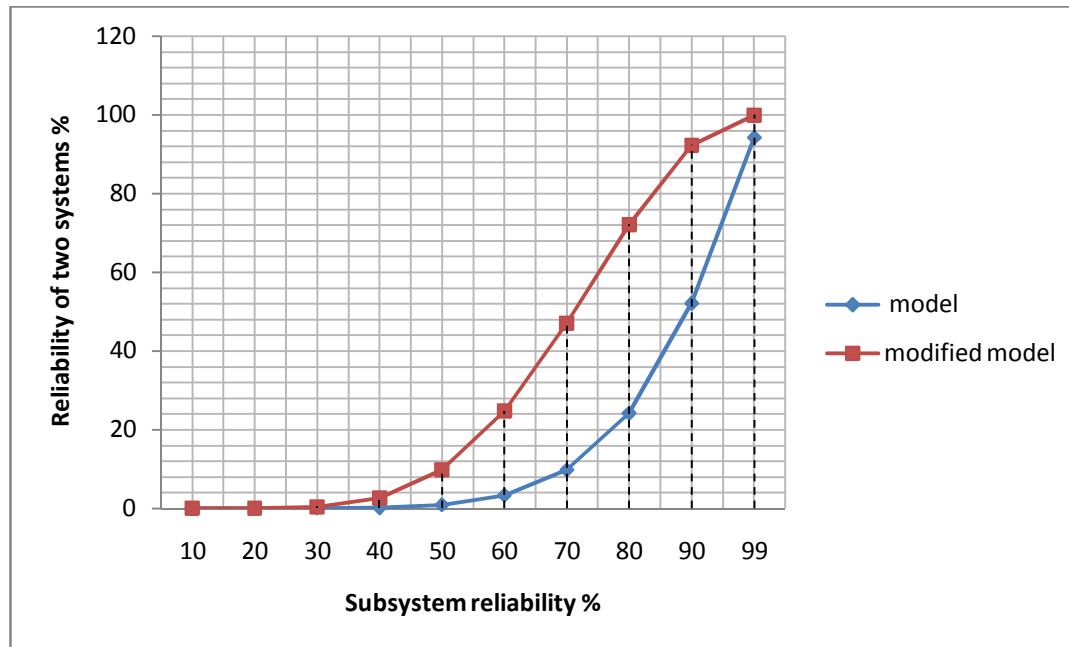


**Figure: 4.4** Graph of reliability of the system versus reliability of subsystem for both models.

The graph of figure 4.4, explains the advantage of the modified model over the station's reliability model. At 20% subsystem reliability the modified model was 0.018% reliable while the station's reliability model was 0.000515% reliable, a difference of 0.0175% in favor of the modified model. At 30% subsystem reliability, the modified model was 0.383% reliable while the model of the system was 0.0158% reliable, a difference of 0.3674% in favor of the modified model.

At 40%, 50% 60%, 70% and 80% subsystem reliabilities there were system reliability differences of 2.44%, 8.94%, 21.4%, 37.3% and 48% respectively, in favor of the modified model. As shown in the graph of figure 4.4 the disparity increases to a large extent on every increment of subsystem reliability.

At 90% subsystem reliability the modified model is 92.3% reliable while the model from the station is 52% reliable, a difference of 40.3%. One can notice the decrease in the increment, at 99% subsystem reliability the modified model is 99.9% reliable while the model from the broadcasting studio is 94% reliable, a difference of 5.9%. This is an indication of the fact that reliability of the system of poor reliability configuration can be very high if the associated subsystem has high reliability. The negative influence of series subsystem on a system is as shown in the differences occurring between the reliability of both models.

The model of Jos broadcasting studio has a characteristic graphical curve that is tending more toward the series reliability configuration curve as shown in figure 4.4. This is because it mixes up series and parallel subsystem configuration on a series chain. The modified model has a typical representation of a graphical curve for parallel configurations on a series chain. The curve is the combination of both series and parallel configuration. That is why it has more of a center of graph inclination between the graphs of parallel and series reliability configuration. Figure 2.1, a graph for series configuration, and figure 2.2 a graph for parallel configuration, are shown in the literature review.

The above analysis shows that series system with parallel subsystem is a configuration that is associated with an improved system. Another method of improving the original model as seen in this research is to acquire equipment with high MTBF specification written in the operations manual. Such equipment will always have low failure rate and high reliability. One can observe from figure 4.4 that as reliability of subsystem approached 90% and above the reliability of the model from the station increased to proportion.

#### **4.8.2 Models' failure rate and subsystems' reliability analysis.**

The failure rate of the both model were also examined for a period of one year to ascertain the influence of failure rate on the reliability of the systems. Assuming a homogeneous failure rate for the purpose of proper assessment of behavior of the model, the modified model was used to quantify the failure rate of the original model. It was discovered that the failure rate of the model was negatively influenced by the failure mode of series subsystem of the model to the extent expatiated on the graph. Figure 4.5 graphically represents the failure behavior of each model as subsystem reliability increases from 10% to 99%.

The graph of figure 4.5 shows how failure rate curve slopes rapidly for the both models. The failure rate of the model is higher than the failure rate of the modified model as reliability increases from 10% to 99%. At 10% reliability, the model had failure rate of 0.0028068 units per hour while the modified model had 0.00257115 units per hour an extra failure rate of 0.00257 units per hour on the part of the model from the station. At 20% reliability, the model had failure rate of 0.0018534 units per hour while the modified model had 0.00131661 units per hour an extra failure rate of 0.00054 units per hour on the part of the model of the studio.

The failure mode of the broadcasting studio shows clearly that the extra failure rate on the part of the model of the studio decreases as reliability increases. At 30%, 40%, 50%, 60% 70% and 80% reliabilities of the associated subsystems there were extra failure rates of 0.000452, 0.000429, 0.000371, 0.000307, 0.000239 and 0.000101 units per hour respectively on the part of the model of the broadcasting studio. Observing the failure trend, it was noticed that the extra failure rate on the part of the model was high but began to reduce as reliability of subsystem increased.

The trend continued in such a way that, when reliability got to 90% for each subsystem the model had failure rate of 0.000099 units per hour while the modified model had 0.0000012 units per hour an extra failure rate of 0.0000981 units per hour on the part of the model of the broadcasting studio. The difference is actually becoming smaller, until the both seem to come together with very close failure rates of  $1 \times 10^{-5}$  and  $1 \times 10^{-7}$  units per hour at 99% subsystem reliability. This shows that the failure rate of both models reduces to insignificance as subsystem approaches higher reliability targeted at 90% and above.

The graph of figure 4.5 has curves that are similar to a typical failure rate graph of the popular Weibull bathtub curve, the curve of the failure rates of equipment. The electronic equipment such as the broadcasting equipment also has special failure rate characteristics that is modeled by the Weibull distribution when the slope  $\beta = 1$  [39].

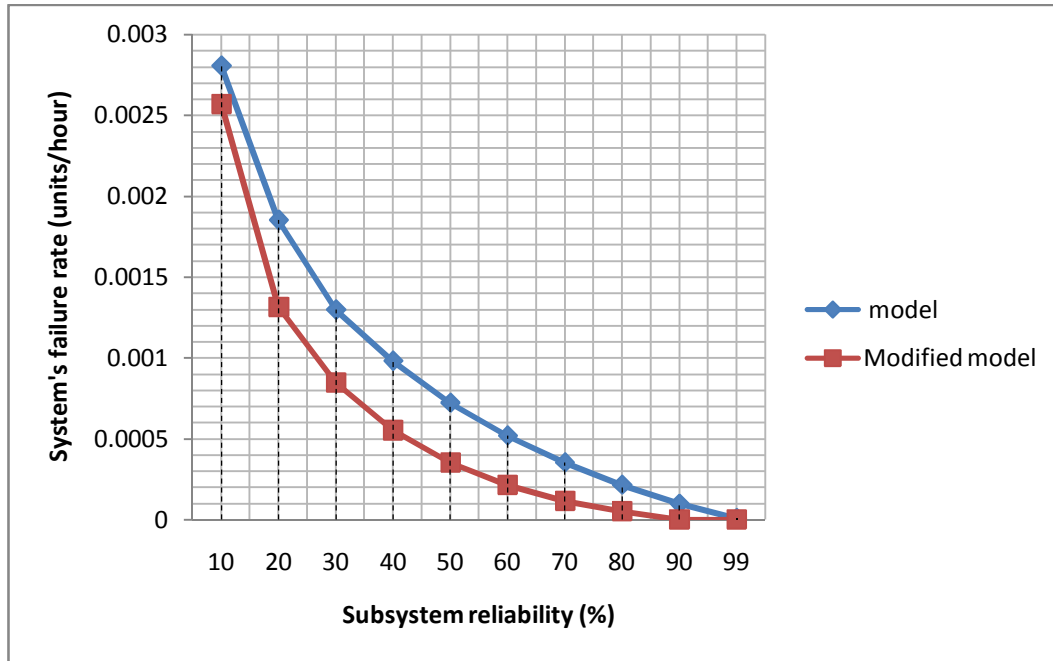


**Figure 4.5** Graph of failure rate for both models

The graph of the useful life of electronic equipment is meant to sloperandomly from left to right with random failure rate according to weibull distribution. The failure rate is assumed to be homogeneous in order to properly assess the fundamental behavior of the models.The curves smoothly slope downward from left to right, indicating that failure rate reduces as reliability increases.

#### 4.9Models' restoration rateand subsystem reliability analysis

Considering the fact that broadcasting equipment is supposed to fail after been used for a long period of time depending on the condition of usage and the efficiency of the equipment. The restoration, maintenance or repair rate was also considered in order to view the behavior of the models.The subsystems used in the broadcasting chain are repairable. The restoration rate for each subsystem wasevaluated and a graph was plotted are as shown in figure 4.6.The restoration rate of the model is given in equation (3.5) as the inverse of the subsystem's mean time to repair. The mean time to repair is given in equation (3.0) and restated as:

$$\lambda_{ij} = \frac{\sum_{j=1}^n \lambda_{ij} \cdot \lambda_{ij}}{\sum_{j=1}^n \lambda_{ij}}$$

In order to observe the characteristics of the models properly, the mean repair time ( $\bar{r}_i$ ) when the  $i$ th component fails was taken as the reverse of the trend for subsystem reliability [0.99, 0.9, 0.8, ..., 0.1], since poor reliability will ideally take a longer time to repair. Each subset of  $\bar{r}_i$  represented that quantity of a hundred hour: which is the sum total of all repair time of the respective subsystem in a year as shown in equation (3.3). Using equations (3.0) and (3.4) for each subset of  $\bar{r}_i$  the restoration rate is evaluated and plotted as shown in figure 4.6.

The curve of figure 4.6 does not start from zero because even at 10% subsystem reliability, restoration rate was not zero, the equipment were repairable. The both model had a single curve because the mean repair time ( $\bar{r}_i$ ) depended on the response of the station's maintenance system within reliability specification. With active redundant subsystem, it was observed that there was a longer time of operation before any subsystem equipment failed.

Even though the failure rate of both model are different they cancel out in equation (3.4) to give the same graph. The graph of figure 4.6 shows the observations of the restoration rate of the models. At 10% subsystem reliability the restoration rate of both models is 0.0101 per hour, at 20% subsystem reliability it is 0.0111 per hour.

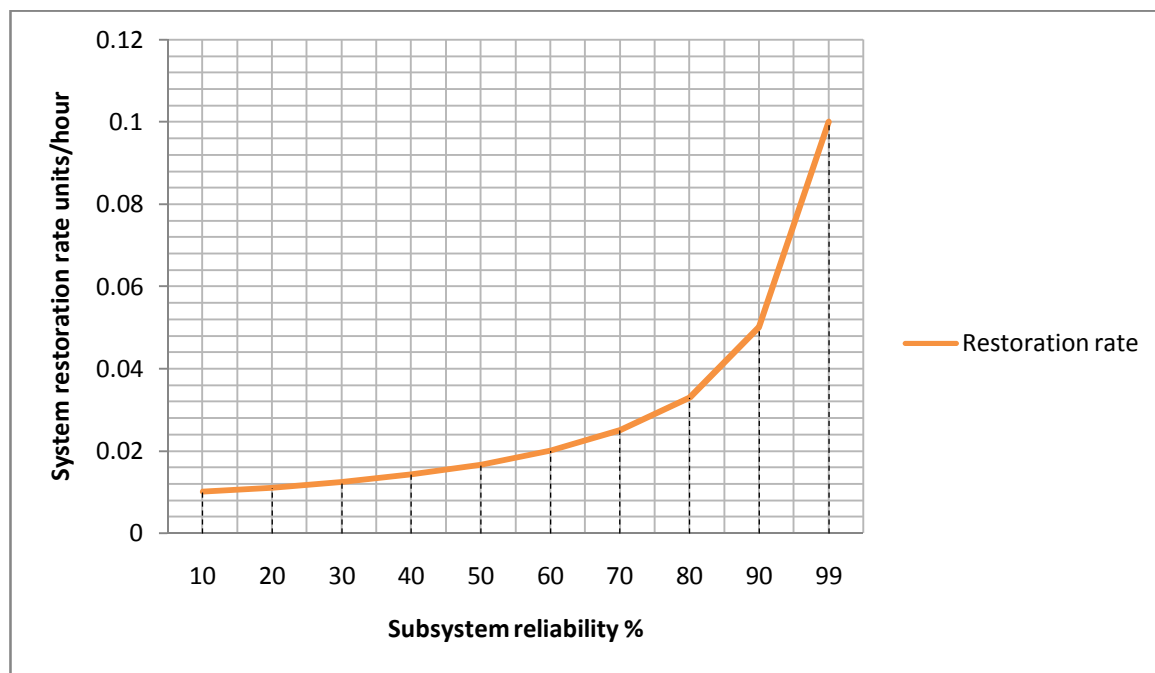


**Figure 4.6** Graph of restoration rate for both the first and the second model.

The system was evaluated from 30% to 70% subsystem reliability. At 30%, 40%, 50%, 60% and 70% subsystem reliabilities, the restoration rates were 0.0125, 0.0143, 0.0167, 0.02 and 0.025 units per hour respectively, the differences became noticeable even though they appear to be small. Then the restoration rate increased to a greater extent from 70% to 99% subsystem reliability. At 80%, 90% and 99% subsystem reliability the restoration rates were 0.033, 0.05 and 0.1 units per hour, one can notice the increment at each stage. These indicated that for every system configuration, the restoration rate is dependent on the subsystem reliability. When the subsystem's reliability is low the restoration rate of the system is equally low but at very high subsystem reliability the restoration rate of the system is equally high.

The graph of figure 4.6 shows a curve that seems to be opposite in characteristic to that of the failure rate, this is concurrent with the expectation of this research; it is because of the repair time of each subsystem; the fact that the restoration rate is a constant value for both model and the respective stages of subsystem reliability [38]. The restoration rate talks more about the equipment that is to be restored back to full functionality. When the restoration rate is too low, it implies that the reliability specifications of the station are not met: either due to the misbehavior of subsystem or due to poor maintenance strategy of the station.

## CHAPTER FIVE

### SUMMARY OF RESULT CONCLUSION AND RECOMMENDATION

#### 5.1. Summary of result

This research work was aimed at developing an analytical reliability model from the configuration of Jos broadcasting equipment. Due to sudden failures often encountered in TV stations; this work was made to serve as a reference to a method of investigating and improving the reliability of broadcasting stations. This research indicates that the model is optimized as the reliability of the equipment that constitutes the system's configuration greatly improves. Also, implementing active redundancy for all series subsystem improved the reliability of the broadcasting station's configuration to the extent expatiated in the preceding chapter and graphically in figure 4.4. The failure rate of the models is shown in figure 4.5 and the restoration rate is exemplified in figure 4.6.

The reliability of Jos TV broadcasting station was found to be 0.33%. This implies that it has a failure rate of 0.0001687 units per hour units per hour and 63 days of operating hours between failures assuming a homogeneous failure rate. The same model was upgraded with subsystem redundancy to form a modified model. The reliability of the modified model was found to be 1.37%, with a failure rate of 0.000653 units per hour and 85 days of operating hours between failures. This emphasizes the importance of subsystem redundancy.

#### 5.2 Conclusion

The strength of any building is its foundation; it suspends the weight of the entire structure. Fundamentally, television broadcasting is possible because of the equipment and the configuration involved in the process. In every faulty configuration the associated broadcasting station may have a system susceptible to persistent failures. Unfortunately, due to the complexity of the control rooms, causes of these failures may not be easily detected even when it may be very costly or grievous to consumers. When the equipment and the associated configuration are very reliable the system will hardly fail and the station will secure and enjoy the trust, confidence and financial involvement of the associated environment.

### 5.3 Recommendation

High reliability of the broadcasting studio requires specialized equipment. The equipment that makes up the system should be the offshoot of proper market search and purchase recommendations from telecommunication authorities or other professional bodies. Reliability of products and proficiency of equipment should be predicted from the MTBF specifications on product operation manual; this is to ensure that equipment used in the broadcasting studio have high reliability. High reliability of the broadcasting studio also demands series systems with parallel subsystem. These recommendations will help engineers and technicians in the broadcasting stations to know the failure mode of the station and salvage the failure situation as the need arises.

This research is however subjected to some limitation highlighted for further research. Subsystem such as the transmitter considered in the broadcasting studio also has subsystems such as slots that are very relevant to the operation of the transmitter. The categorization of the slots into parallel or series connectivity and the construction of their reliability configuration require intensive investigation. The acquisition and application of such information to this work will improve the behavior of the models.

This research did not improve the quality or capacity of the broadcasted signal. It analyses and qualifies the reliability of configurations as bases for evaluation and sustenance of broadcasted signal. Further research could help the quality and capacity building for the models, which will also involve the choice of the nature of equipment employed.

Reliability at electronic element level was not considered in this research work. More investigation on the reliability of discrete components and integrated circuits will also add to the reliability of the result from the models.

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## APPENDIX A

### Step (5) Development of the modified model (Video line)

#### Reliability analysis of the modified model

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From figure 3.8 the power supply is connected in parallel with each other and in series with the system as expressed in equation (3.6)

$$R_1 = R_{P, \text{supply}} = 1 - (1 - R_{\text{GEN}}) \times (1 - R_{\text{PHCN}}) \quad (3.6)$$

The two cameras are connected in series with their cable equalizers in  $R_{\text{CAM1}} \times R_{\text{C.EQ}}$  and  $R_{\text{CAM2}} \times R_{\text{C.EQ}}$ , Such that  $R_{\text{CAM1}} \times R_{\text{C.EQ}}$ ,  $R_{\text{CAM2}} \times R_{\text{C.EQ}}$  and  $R_{\text{VCR}}$  are all in parallel but their combination is in series with  $R_{\text{SPG}}$  as shown below:

$$R_{21} = 1 - (1 - R_{\text{CAM1}} \times R_{\text{C.EQ}}) \times (1 - R_{\text{CAM2}} \times R_{\text{C.EQ}}) \times (1 - R_{\text{VCR}})] \times R_{\text{SPG}}$$

The resultant of  $R_{21}$  is in parallel with the parallel combination of  $R_{\text{DVD1}}$ ,  $R_{\text{DVD2}}$ ,  $R_{\text{SAT1}}$ ,  $R_{\text{COMP}}$ , and  $R_{\text{SAT2}}$ , The equipment of the outside broadcasting van is connected in series with cable equalizer and represented in a series form:

$$R_{\text{RS}} = R_{\text{OB.VAN}} \times R_{\text{C.EQ}}$$

The resultant of the parallel combinations of  $R_2$  is expressed as stated in equation (3.7)

$$\begin{aligned} R_2 = \{ & 1 - [(1 - (1 - R_{\text{CAM1}} \times R_{\text{C.EQ}}) \times (1 - R_{\text{CAM2}} \times R_{\text{C.EQ}}) \times (1 - R_{\text{VTR/VCR}})] \times R_{\text{SPG}}] \times \\ & (1 - R_{\text{DVD1}}) \times (1 - R_{\text{DVD2}}) \times (1 - R_{\text{SAT.R1}}) \times (1 - R_{\text{COMP}}) \times (1 - R_{\text{SAT.R2}}) \times \\ & (1 - R_{\text{OB.VAN}} \times R_{\text{C.EQ}}) \times (1 - R_{\text{C.G}})] \} \quad (3.7) \end{aligned}$$

There two video Matrix/production switcher (VM/PS) are connected in parallel as stated in equation (3.8)

$$R_3 = 1 - (1 - R_{\text{VM/PS}}) \times (1 - R_{\text{VM/PS}}) \quad (3.8)$$

There are two time base correctors (TBC) connected in parallel and expressed as equation (3.9)

$$R_4 = 1 - (1 - R_{\text{TBC}}) \times (1 - R_{\text{TBC}}) \quad (3.9)$$

There are two transmission video distribution amplifier connected in parallel expressed as equation (4.0)

$$\mathcal{R}_{\mathcal{V}} = 1 - (1 - \mathcal{R}_{\text{TX VDA}}) \times (1 - \mathcal{R}_{\text{TX VDA}}) \quad (4.0)$$

There are also two transmitters connected in parallel expressed as stated in equation (4.1)

$$\mathcal{R}_{\mathcal{T}} = 1 - (1 - \mathcal{R}_{\text{TX1}}) \times (1 - \mathcal{R}_{\text{TX2}}) \quad (4.1)$$

Equations (3.8) to (4.1) parallel configuration expressions are combined by series connection to give equation (4.2) as follows:

$$\begin{aligned} \mathcal{R}_{\text{Sub}} = & [1 - (1 - \mathcal{R}_{\text{VM/PS}}) \times (1 - \mathcal{R}_{\text{VM/PS}})] \times [1 - (1 - \mathcal{R}_{\text{TBC}}) \times (1 - \mathcal{R}_{\text{TBC}})] \times [1 - (1 - \mathcal{R}_{\text{TX VDA}}) \times \\ & (1 - \mathcal{R}_{\text{TX VDA}})] \times [1 - (1 - \mathcal{R}_{\text{TX1}}) \times (1 - \mathcal{R}_{\text{TX2}})] \end{aligned} \quad (4.2)$$

So that the whole system which is the combination of  $\mathcal{R}_{\mathcal{V}}$ ,  $\mathcal{R}_{\mathcal{T}}$ ,  $\mathcal{R}_{\mathcal{V}}$ ,  $\mathcal{R}_{\mathcal{V}}$ ,  $\mathcal{R}_{\mathcal{V}}$ ,  $\mathcal{R}_{\mathcal{V}}$ ,  $\mathcal{R}_{\mathcal{V}}$  major subsystem and it is expressed as stated in equation (4.3)

$$\begin{aligned} \mathcal{R}_{\text{System}} = & [1 - (1 - \mathcal{R}_{\text{GEN}}) \times (1 - \mathcal{R}_{\text{PHCN}})] \times \{1 - [1 - (1 - \mathcal{R}_{\text{CAM1 R.C.EQ}}) \times (1 - \mathcal{R}_{\text{CAM2 R.C.EQ}}) \times \\ & (1 - \mathcal{R}_{\text{VCR}})] \times \mathcal{R}_{\text{SPG}}] \times (1 - \mathcal{R}_{\text{DVD1}}) \times (1 - \mathcal{R}_{\text{DVD2}}) \times (1 - \mathcal{R}_{\text{SAT.R1}}) \times (1 - \mathcal{R}_{\text{COMP}}) \times \\ & (1 - \mathcal{R}_{\text{SAT.R2}}) \times (1 - \mathcal{R}_{\text{OB VAN R.C.EQ}}) \times (1 - \mathcal{R}_{\text{C.G}})] \} \times [1 - (1 - \mathcal{R}_{\text{VM/PS}}) \times (1 - \mathcal{R}_{\text{VM/PS}})] \times \\ & [1 - (1 - \mathcal{R}_{\text{TBC}}) \times (1 - \mathcal{R}_{\text{TBC}})] \times [1 - (1 - \mathcal{R}_{\text{TX VDA}}) \times (1 - \mathcal{R}_{\text{TX VDA}})] \times [1 - (1 - \mathcal{R}_{\text{TX1}}) \times \\ & (1 - \mathcal{R}_{\text{TX2}})] \end{aligned} \quad (4.3)$$

## APPENDIX B

### Step (5) Development of the modified model (audio line)

#### Reliability analysis of the modified model

#### Chapter 4Page 48

From figure 3.9, the power supply is the generator and power holding company PHCN connected in parallel as expressed in equation (4.4)

$$R_{PS} = 1 - Q_1 - Q_{PS} Q_1 (1 - Q_{PS}) \quad (4.4)$$

Four Microphones (MIC) and three Machines for audio sources are connected in parallel and expressed as stated in equation (4.5):

$$R_{PS} = 1 - Q_1 - R_{MIC} Q_1 - R_{MIC} Q_1 - R_{MIC} Q_1 - R_{MIC} Q_1$$

$$Q_1 - R_{MIC} Q_1 - R_{MIC} Q_1 (1 - R_{MIC}) \quad (4.5)$$

The audio consol/ keyboard switch (AUD.MIX/KBS) is connected in parallel as stated in equation (4.6).

$$R_{PS} = 1 - Q_1 - Q_{AUD.MIX/KBS} Q_1 (1 - Q_{AUD.MIX/KBS}). \quad (4.6)$$

The high power amplifier as connected in parallel as shown in equation (4.7)

$$R_{PS} = 1 - Q_1 - Q_{H.P.A} Q_1 (1 - Q_{H.P.A}) \quad (4.7)$$

The audio distribution amplifier (ADA) is also connected in parallel as expressed in equation (4.8)

$$R_{PS} = 1 - Q_1 - Q_{ADA} Q_1 (1 - Q_{ADA}) \quad (4.8)$$

And finally the transmitters are connected in parallel and expressed as stated in equation (4.9)

$$R_{PS} = 1 - (1 - Q_{TX})(1 - Q_{TX}) \quad (4.9)$$

Reliability model of the system for audio line combines equations (4.3) to (4.8) to form an expression as stated in equation (5.0)

$$\begin{aligned}
R_2 = & \frac{1}{2} - \frac{1}{2} - R_{222} \frac{1}{2} - R_{2222} \frac{1}{2} - \frac{1}{2} - R_{222} \frac{1}{2} - R_{2222} \frac{1}{2} - R_{222} \frac{1}{2} - R_{2222} \frac{1}{2} - \\
& R_{222} \frac{1}{2} - R_{222} \frac{1}{2} - R_{222} \frac{1}{2} \times [1 - \frac{1}{2} - R_{2222} \frac{1}{2} - R_{2222} \frac{1}{2} \times [1 - \frac{1}{2} - R_{222} \frac{1}{2} - \\
& R_{222} \frac{1}{2} \times [1 - (1 - R_{222}) (1 - R_{222})] \quad (5.0)
\end{aligned}$$

But because the reliability of the power sources and transmitter have been evaluated as equations(3.6) and (4.1) they are excluded, equation (5.0) can then be expressed as stated in equation (5.1)

$$R_{\square} = \square_1 - \square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1 \times [1 - \square_1 - R_{\square\square\square\square\square\square\square}\square_1 - R_{\square\square\square\square\square\square\square}\square_1] \times [1 - \square_1 - R_{\square\square\square}\square_1 - R_{\square\square\square}\square_1] \quad (5.1)$$

## The ModifiedModel

[illegible]

## Appendix c

**Page 22 Literature review Table 4**

**Series system**

**Subsystem reliability versus system reliability tableplatted based on 2,3,4 and 5 subsystem**

| Subsystem's<br>reliability | 2component<br>system | 3component<br>system | 4component<br>system | 5component<br>system |
|----------------------------|----------------------|----------------------|----------------------|----------------------|
| 0.1                        | 0.01                 | 0.001                | 0.0001               | 0.00001              |
| 0.2                        | 0.04                 | 0.008                | 0.0016               | 0.00032              |
| 0.3                        | 0.09                 | 0.027                | 0.0018               | 0.00243              |
| 0.4                        | 0.16                 | 0.064                | 0.0256               | 0.01024              |
| 0.5                        | 0.25                 | 0.125                | 0.0625               | 0.03125              |
| 0.6                        | 0.36                 | 0.216                | 0.1296               | 0.07776              |
| 0.7                        | 0.49                 | 0.343                | 0.2401               | 0.16807              |
| 0.8                        | 0.64                 | 0.512                | 0.4096               | 0.32768              |
| 0.9                        | 0.81                 | 0.729                | 0.6561               | 0.59049              |
| 0.99                       | 0.98                 | 0.970                | 0.9606               | 0.95099              |

**Page 24 Literature review Table 5**

**Parallel system**

**Subsystem reliability versus system reliability table platted based on 2, 3, 4 and 5 subsystem**

| Subsystem<br>reliability | 2component<br>system | 3component<br>system | 4component<br>system | 5component<br>system |
|--------------------------|----------------------|----------------------|----------------------|----------------------|
| 0.10                     | 0.1900               | 0.271000             | 0.3439000            | 0.40951000           |
| 0.20                     | 0.3600               | 0.488000             | 0.5904000            | 0.67232000           |
| 0.30                     | 0.5100               | 0.657000             | 0.7599000            | 0.83193000           |
| 0.40                     | 0.6400               | 0.784000             | 0.8704000            | 0.92224000           |
| 0.50                     | 0.7500               | 0.875000             | 0.9375000            | 0.96875000           |
| 0.60                     | 0.8400               | 0.936000             | 0.9744000            | 0.98976000           |
| 0.70                     | 0.9100               | 0.975000             | 0.9919000            | 0.99757000           |
| 0.80                     | 0.9600               | 0.992000             | 0.9984000            | 0.99968000           |
| 0.90                     | 0.9900               | 0.999000             | 0.9999000            | 0.99999000           |
| 0.99                     | 0.9999               | 0.999999             | 9.9999990            | 0.99999999           |

**System reliability versus number of hours between failures for the model**  
**Chapter 4, page 58 Table 6**

| Subsystem reliability % (model) | Number of hrs between failures |
|---------------------------------|--------------------------------|
| 10                              | 00356                          |
| 20                              | 00540                          |
| 30                              | 00751                          |
| 40                              | 01018                          |
| 50                              | 01383                          |
| 60                              | 01922                          |
| 70                              | 02820                          |
| 80                              | 04624                          |
| 90                              | 10072                          |
| 99                              | 108,586                        |

**System reliability versus number of hours between failures for the modified model**

**Chapter 4, page 60 Table 7**

| Subsystem reliability% (model) | Number of hrs between failures |
|--------------------------------|--------------------------------|
| 10                             | 00389                          |
| 20                             | 00760                          |
| 30                             | 01181                          |
| 40                             | 01809                          |
| 50                             | 02833                          |
| 60                             | 04697                          |
| 70                             | 08701                          |
| 80                             | 20115                          |
| 90                             | 81713                          |
| 99                             | 8212089                        |

**Subsystem reliability versus model and modified model reliability**

**Chapter 4, page 62 Table 8**

| Subsystem Reliability % | Model      | Modified model          |
|-------------------------|------------|-------------------------|
| 10                      | 0.00000098 | $4.6099 \times 10^{-7}$ |
| 20                      | 0.00051486 | 0.01751144              |
| 30                      | 0.01586094 | 0.38284443              |
| 40                      | 0.15776681 | 2.6468877               |
| 50                      | 0.86325784 | 9.8330442               |
| 60                      | 3.27889480 | 24.6884816              |
| 70                      | 9.73695940 | 46.9984434              |
| 80                      | 24.1534310 | 72.1364069              |
| 90                      | 52.0865173 | 92.2744427              |
| 99                      | 94.1290000 | 99.9200279              |

**Appendix H**

# Subsystem failure rate versus model and modified model failure rate

Chapter 4, page 65 Table 9

| Subsystem reliability % | Model's failure rate units per hour | Modified model units per hour |
|-------------------------|-------------------------------------|-------------------------------|
| 10                      | 0.0028068                           | 0.00257115                    |
| 20                      | 0.00185339                          | 0.00131661                    |
| 30                      | 0.00129877                          | 0.00084708                    |
| 40                      | 0.00098201                          | 0.00055278                    |
| 50                      | 0.00072332                          | 0.00035303                    |
| 60                      | 0.00052019                          | 0.00021291                    |
| 70                      | 0.00035452                          | 0.00011492                    |
| 80                      | 0.00021625                          | 0.00004971                    |
| 90                      | 0.00009928                          | 1.224E-06                     |
| 99                      | 0.00000921                          | 1.22E-07                      |

**Subsystem reliability versussystem restoration rate**

**Chapter 4, page 66 Table 10**

| Subsystem reliability % | System Restoration rate units per hour |
|-------------------------|----------------------------------------|
| 10                      | 0.0101                                 |
| 20                      | 0.0111                                 |
| 30                      | 0.0125                                 |
| 40                      | 0.0143                                 |
| 50                      | 0.0167                                 |
| 60                      | 0.0200                                 |
| 70                      | 0.0250                                 |
| 80                      | 0.0330                                 |
| 90                      | 0.0500                                 |