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Sustainable framework for a geostationary satellite control earth station system using parallel configuration

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ABSTRACT

Earth station system plays an important role to ensure that a satellite communication system runs efficiently. Redundancies of the subsystems and regular maintenance planning can improve the earth station system. Organising system affordability can be challenging as more redundancies would acquire more maintenance. Thus, a sustainable framework that considers an earth station system's reliability, cost, and maintainability was modelled. 2-parallel, 3-parallel, and 4-parallel earth station system configurations were studied with five mean time between failures (MTBF). The results showed that an earth station that was configured with 2-parallel configuration provided an optimum reliability system performance though both 3-parallel and 4-parallel configuration provided higher reliability. Moreover, the 2-parallel configuration was also cheaper in terms of operational cost if compared to the 3-parallel and the 4-parallel configurations. Hence, this sustainable framework comprising the reliability and operational cost elements were modelled based on the 2-parallel configuration with the proposed maintenance activities. Moreover, the computed root mean square (RMS) values for both new reliability and new operational cost models yielded smallest values of 20.84% and 22.82% respectively. Thus, these RMS values for both reliability and operational cost models based on 2-parallel configuration are suitable to be applied in the earth station system design.

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1. INTRODUCTION

The earth station services are particularly useful for missions that require frequent, short-duration contacts with high bandwidth utilization and capable to uphold longer latency durations due to orbital dynamics and station visibility [1]. Malfunctions that cause system irregularities and failures are expected in the earth station system. A typical case of a failure that could be brought by distorted wireless communication and intermittent connection during cell handovers in cellular networks is data loss in systems [2]. Subsystem redundancies, extensive testing during the development stage, and the usage of only the best components may increase the reliability of an earth station system [3]. Furthermore, regular maintenance efforts are necessary to minimise cost overruns and any unexpected breakdowns. Each subsystem's failure rate in the earth station system is a significant indication of whether the subsystem is functional or not. A catastrophic incident, such as equipment failure can cause the satellite service provider to lose lots of money. Therefore, system reliability design is critical to guarantee effectiveness of the operating service [4]. Not many research works are done on designing a simple but robust earth station system with a straightforward reliability model that can last longer and yields the cheapest version. Many previous works focused too much on the technical and complexity part of the design without realizing how vital the operational cost is [2]-[4].

Would more redundancies also increase the cost? How can the cost and technical (reliability and maintenance) be balanced?. In addition, once the satellite is launched, relevant maintenance tasks must be carried out in the earth station system to make sure that no failures occurred which then can disrupt the transmission process. In turn, by having the right maintenance activities can also prevent a cost blowout.

Thus, the resilience of a geostationary satellite control earth station system can be refined by constructing a sustainable framework. This framework integrates three important elements: reliability and operational cost models as well as the proposed maintenance activities which are the main contributions of this research. This framework ought to maintain the optimum performance of an earth station system. Moreover, this research concentrates on ways to reduce the costs while promoting the economic growth, which is in line with SDG goal number 8 (Decent Work and Economic Growth). Additionally, this research is also linked to the SDG goal number 9 (Industry, Innovation, and Infrastructure), which emphasizes on a sustainable engineering system framework to prevent any unexpected failures.

In this context, the reliability, the operational cost, and the maintainability were the three key components conveyed by the term "sustainable". The structure of this article is as follows. Section 2 provides further depth into the system summary consisting of the technical background of system reliability, the operational cost and maintainability component to ensure that the earth station system operates to its highest potential. Section 3 explains the research methodology. Meanwhile, section 4 discusses the results and discussion. Finally, section 5 covers the conclusion and practical guidelines for further research.

2. LITERATURE REVIEW

The literature on the geostationary satellite control earth station system is thoroughly examined in this part. A fixed-position satellite in a geosynchronous orbit 35, 786 kilometres above the equator, where the great majority of communication satellites are located, is referred to as a geostationary satellite (also known as a GEO satellite) [5]. One of its numerous applications is direct-to-home satellite broadcasting, or DTH for short [6]. An earth station and a space station are the typical components of a satellite communication system. The earth station system, also known as the ground station system, is composed of tracking, telemetry, and command systems, whereas the space station is only consisting of satellites [7]. All subsystems must function properly so that they can operate collectively to provide a reliable earth station system. The subsystems also include thousands of components that require meticulous maintenance [8].

2.1. Model of a basic earth station system

Figure 1 depicts the fundamental earth station system, which is made up of the computer control, baseband, and RF/antenna subsystems [9]. The computer control subsystem serves as the primary point of communication between satellite control personnel and the satellite [9]. The system controls the near real-time processing of satellite telemetry, including the concurrent processing, display, and archiving of satellite telemetry streams. To avoid data loss, the system is additionally linked to real-time and storage servers. The satellite engineering station (SES), orbital analysis station (OAS), and status and control station (SAC) workstations are simultaneously served by the real-time server, which manages satellite telemetry. Switch control is provided by the SAC workstation, which also receives and shows all equipment status for the computer control system [9].

One essential element of an earth station baseband system is the integration of telemetry command and ranging unit. It involves a range of activities, including data processing, satellite control, and satellite ranging. The RF/antenna system, which is most vulnerable to failure, is made up of the transmit chains of uplink and downlink, and antenna, as shown in Figure 1 by the red dots [10]. The high-power amplifier, up-converter, and modulator that make up the uplink transmit chain and the down-converter, low noise amplifier, and demodulator that make up the downlink transmit chain are used by the antenna to send and receive telemetry from a satellite, respectively.

An earth station model is often developed using a simple framework. Since each of the aforementioned subsystems is involved in both uplink and downlink operations, the end-to-end system includes two power amplifiers, up-converters, and modulators for the broadcasting part and a down-converter, low noise amplifier, and demodulator for the receiving part. The 14 subsystems of the RF/antenna system function together to deliver a full signal processing. The focus of this research is on the red marked dots in Figure 1 which is RF/antenna system as failures occur in this system [6], [10].

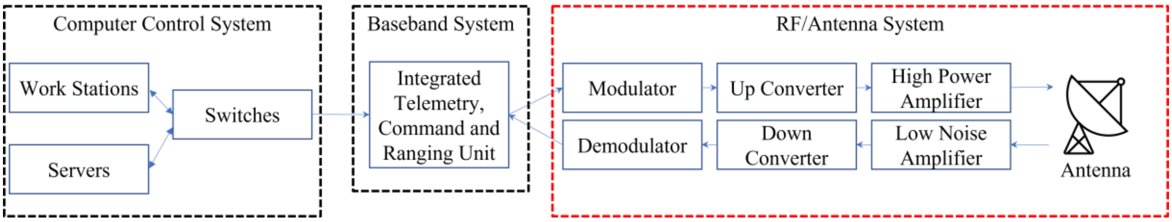

Figure 1. Basic satellite earth station system [9]

2.2. Parallel structures of the earth station system

This research focused on *n*-parallel RF/antenna system designs. 2-parallel, 3-parallel, and 4-parallel configurations were selected to assess the reliability performance and recommended maintenance activities for each subsystem in the designated configurations. The services that the system can provide are thus represented by the quality performance measures. These measures can be used to distinguish realistic performance requirements [11].

Figure 2 shows the *n*-parallel configurations, which are marked in red dots, and n indicates the number of redundant components. Each station contains two redundant units in a 2-parallel configuration, three redundant units in a 3-parallel configuration, and four redundant units in a 4-parallel configuration. The 2-parallel arrangement is less expensive than the 3-parallel and 4-parallel configurations, although it has a higher failure rate. However, the 3-parallel and 4-parallel configurations were considered for this research because the reliability and operational cost values may or may not show significant results that may or may not lower the rate of system failure and as well as the low-cost consumption. Additionally, the mean-time-between-failures (MTBF) of the system was assessed; the greater the MTBF number, the higher the potential gain in a system's reliability.

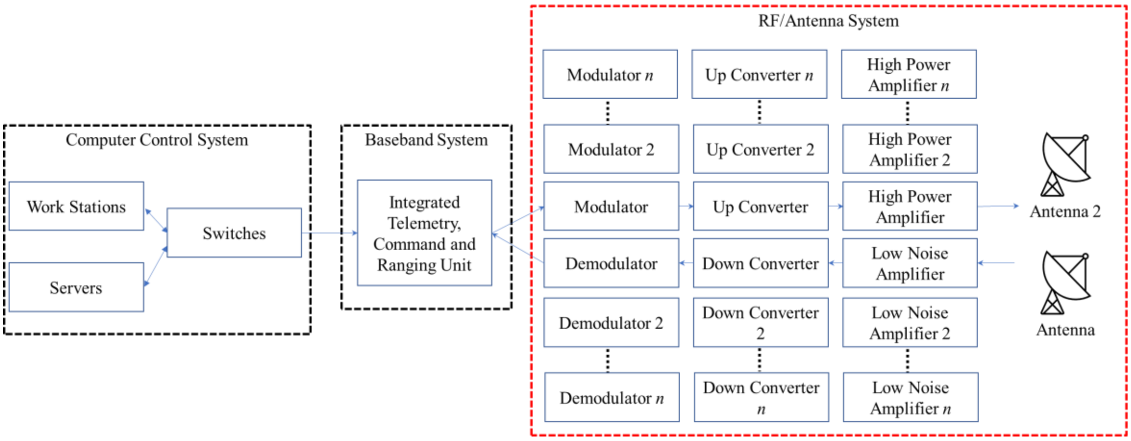

Figure 2. *n*-Parallel earth station system model

2.3. Design for an earth station system reliability

The possibility that a system will operate as intended for a specified amount of time under specific circumstances is a standard basis of reliability [12]. In other words, reliability is the likelihood of completing a set of tasks within a set time frame, without error, and with respect to a set of requirements [12]. One of the most important aspects of developing reliability models and conducting reliability analysis research is reliability model evaluation [13]. It is important to understand that each model is founded on a set of presumptions, the validity of which affects how the model performs [14]. Primarily, how the model is being managed in a project is also important to ensure the system's functionality and longevity [15].

When a design issue arises, optimisation is essential. As an illustration, the optimisation is necessary to include several systematic parameters for an earth station system design. Such an issue requires a comprehensive computational methodology and cross-disciplinary analysis [16]. In a system reliability analysis, these two important elements which are failure rate and MTBF values are required. Hence, in the next section, these two elements are discussed.

2.4. Failure rate and mean-time-between failures

The most crucial element in attaining a system operational sustainability is the design for reliability. The probability that an earth station system performs its defined mission effectively when used within the specified operating parameters and for a specific duration is used to determine the system reliability. The system failure rate does affect the reliability. The frequency in which failures occur over a certain period is known as the failure rate [8]. The hourly failure rate is expressed as in (1),

$$\lambda = \frac{(\text{number of failures})}{(\text{total operating hours})} \tag{1}$$

where, λ is known as the failure rate.

In general, there are many ways to express the number of failures. They can be expressed in terms of the number of failures per hour, the percentage of failures per 1,000 hours, and the number of failures per million hours [6]. MTBF are used in the calculation of a repairable system. Whereas the mean time to failures are used in the computation of a system which is nonrepairable [17]. Both terms can be used when the failure rates are constant. The system mean life, or MTBF, of electrical and electronic equipment disperses exponentially and is represented by (2),

$$M = \frac{1}{\lambda} \tag{2}$$

where:
M = MTBF
λ = failure rate

2.4.1. Reliability measures

Reliability can be defined as in (3),

$$R(t) = e^{-t/M} = e^{-\lambda t} \tag{3}$$

where, M is the MTBF and λ is the failure rate [8]. Because of its oblivious nature and relatively accurate representation of the time to failure of electronic components, the earth station reliability in this research is considered to be exponential [18].

A parallel network is one in which several identical components are used simultaneously, and the failure of all components is required to bring the entire system down [19]. Figure 3 illustrates a parallel network with two components. Assuming *A* and *B* are identical, the system will work if either *A* or *B*, or both are operational. The reliability is defined as in (4). Next, consider a network with three parallel components as seen in Figure 4, whereby the network reliability is expressed as in (5),

$$R = R_A + R_B - (R_A)(R_B) \tag{4}$$

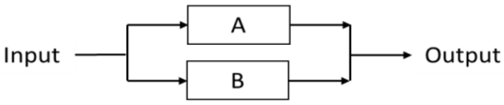

Figure 3. A 2- parallel configured network [17]

$$R = 1 - (1 - R_A)(1 - R_B)(1 - R_C) \tag{5}$$

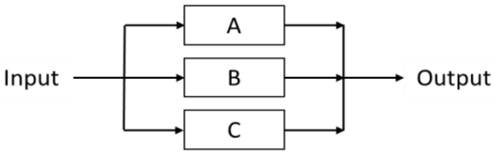

Figure 4. A 3-parallel configured network [17]

If components *A*–*C* are identical, the reliability expression may be simplified as in (6),

$$R = 1 - (1 - R)^3 \tag{6}$$

for a system with three parallel components. Therefore, the reliability given for a system with n identical parts is expressed in (7).

$$R = 1 - (1 - R)^n \tag{7}$$

This research utilizes 2-parallel, 3-parallel, and 4-parallel configurations. The 2-parallel configuration is used by MEASAT in their earth station design since it is the most ideal [10]. Therefore, in a two-parallel configuration, one earth station system is operational, and a backup redundant unit is preserved. Whereas the 3- and 4-parallel configurations were examined for research purposes.

2.5. An earth station system affordability

The capabilities of a system may vary during its lifespan under operational settings because these settings are subjected to change and might evolve unexpectedly. As a result, affordability must be determined from both inside and outside the system of interest bounds (SOI) [20]. According to The International Council on Systems Engineering (INCOSE) Affordability Working Group, affordability aims to achieve mission objectives that are in line with strategic organisational and investment demands while balancing cost, system performance, and schedule restrictions over the system life [21]. Additionally, the SOI growing limits must be viewed as both main and enabling systems. The primary system must fulfil the requirements of a mission, whereas the enabling system maintains critical functionality throughout the system lifespan. To create a single system of systems (SOS), which is the full SOI, the primary and enabling systems should be combined [22]. The extent to which these systems can be integrated may ultimately determine how relevant they are.

The SOS methodology must be used for procurement while the system design phase and operational system are used to determine and measure affordability. By achieving the optimal total cost and utilising (8), it is ideal to minimise the overall expenses [23], including failure costs and maintenance costs of all system components.

$$\sum_{i=1}^{I}\sum_{t=1}^{T} C_M\,(i,t) + \sum_{i=1}^{I}\sum_{t=1}^{T} P_F\,(i,t) C_F(i,t) \tag{8}$$

where, C_F is failure costs that vary depending on the system component, *i* and the maintenance period, *t*. The probability of failure, P_F is influenced by the component and the time. The maintenance period of relative error is related to failure probability. Additionally, maintenance costs, C_M is determined by the component and time because the condition or maintenance activity may change.

3. RESEARCH METHOD

This section discusses the three methods which were carried out to obtain the mentioned results in Section 4. The first one is the technical modelling consists of Monte Carlo simulation which was used to model the reliability. The second one is the financial modelling which was used to model the cost. The last one is the proposed maintenance activities received from the discussion with the MEASAT personnel [6].

3.1. Technical modelling

The technical modelling was performed which involves with the reliability calculation and modelling. In this research, Monte Carlo simulation delivered the highest level of precision and flexibility and therefore to be adopted [18]. Monte Carlo simulation refers to the application of numerical repetitive simulation of system performance [24]. By simulating the Monte Carlo over a specific system lifespan and deriving the system failure frequency and availability amongst others, a statistic of the system performance can be generated [18]. The earth station system was modelled in this research over a period of 10 years. Then, to calculate a statistical outcome life simulation was performed through many trials.

First, the research gaps were identified from the earth station system. It was found that failures usually occurred in the RF/Antenna system [6]. So, the research was focused on the said system. Next, the three types of parallel configurations were included in the earth station which were 2-parallel, 3-parallel, and 4-parallel configurations. The 2-parallel, had 2 redundant units in the system. While 3 and 4-parallel configurations had each 3 and 4 redundant units respectively. The second step was to obtain the reliability graphs using Monte Carlo simulation as shown in Figure 5 using MATLAB software. The reliability graphs were plotted against the lifecycle of the satellite system which in this case was 10 years with five different MTBF values respectively for each parallel configuration. Next, the parallel configuration which gave the optimum reliability values was chosen to model the reliability. Then, the RMS value was computed to validate whether the model could be used for future development or not. The smaller RMS value was preferred.

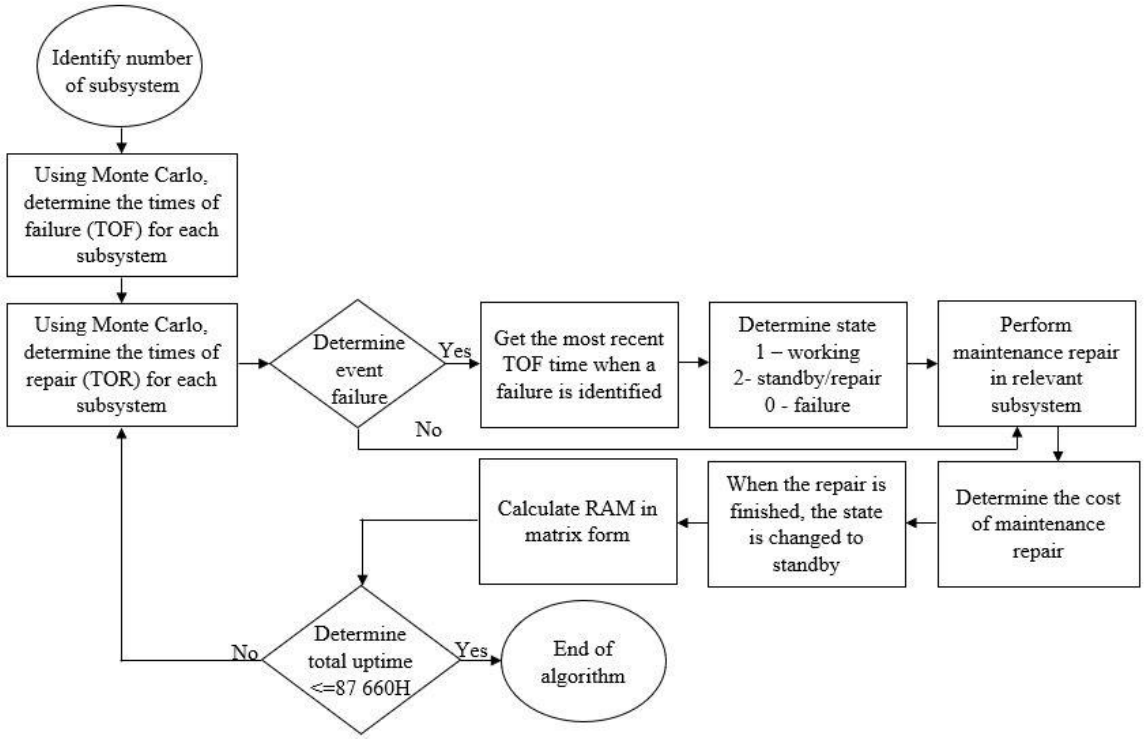

Figure 5. Technical simulation flowchart to deduce the reliability component using Monte Carlo

3.2. Financial modelling

The second step is to obtain an affordability profile from each parallel configuration and then, the operational cost was calculated and modelled. In (8) was used to compute the operational cost. This operational cost involved with preventive and corrective costs. In order to prevent unexpected equipment failure, preventive maintenance is carried out on working systems [25]. According to [26], establishing a lower corrective maintenance cost to preventative maintenance cost ratio results in optimal operational costs with the highest level of system reliability. The configuration which had the lowest cost consumption was used in the cost modelling. Next, the RMS value was also computed to validate whether the model could be used in the future or not. Also in this model, smaller RMS value was preferred.

3.3. Maintenance activities

Although maintainability and maintenance have multiple interpretations, there are some similarities between them. Generally, maintainability implies to a system ability to be maintained, whereas maintenance is a set of instructions taken to keep the system working effectively. Maintainability is incorporated into design, whereas maintenance is the outcome of the design [18]. Signal processing using a range of data processing techniques, sensor-based data collection, and feature development, which involves obtaining parameters to create the monitored equipment status, are the three processes that should be performed during maintenance [27]. On top of that, detection of failure can be retrieved through online monitoring, whereby the system current state information is collected through the stored date in which the system past state information is recorded.

Figure 6 illustrates an earth station system's overall maintainability. As soon as a breakdown is discovered, corrective maintenance must be performed, either by curative maintenance (which includes long-term repairs for issues) or palliative maintenance (which includes temporary fixes for issues). On the other side, when a breakdown is expected, preventative maintenance must be carried out. In this case, there are four more methods that may be used: systematic maintenance, forecast maintenance, conditional maintenance, and proactive maintenance.

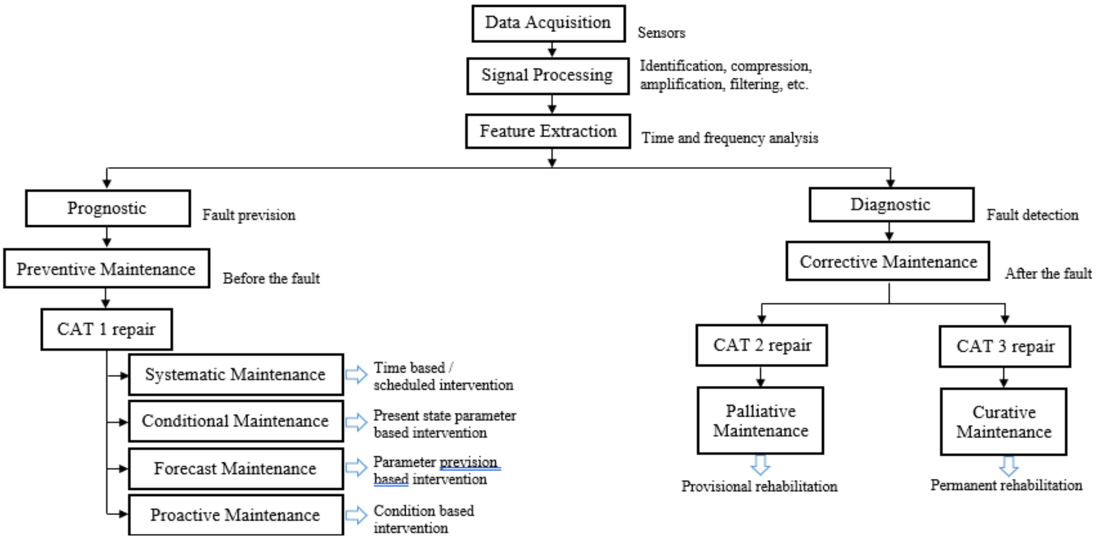

Figure 6. Maintainability overview of an earth station system [27]

4. RESULTS AND DISCUSSION

MATLAB's Monte Carlo simulation was used to carry out the first development step of the technical simulation as depicted in Figure 6. Figures 7-9, respectively, show the earth station system reliability based on 2-parallel, 3-parallel, and 4-parallel configurations with five distinct MTBF values, which are first, third, fifth, seventh, and tenth years. Each graph from the simulations revealed a significant reduction of system reliability during the second and third year of satellite operation. It is because high failure frequency reduces the system reliability to deliver the system’s optimum efficiency. In the first several years of operation, there were many system failures, which made it difficult to stabilise the system reliability.

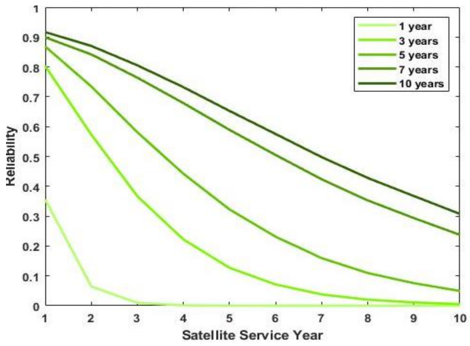

Figure 7. System reliability of 2-parallel configuration with 5 different MTBF

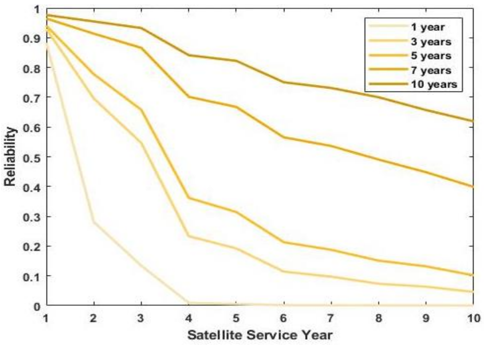

Figure 8. System reliability of 3-parallel configuration with 5 different MTBF

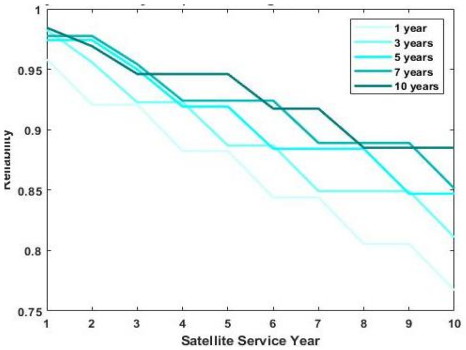

Figure 9. System reliability of 4-parallel configuration with 5 different MTBF

As can be seen from the three graphs, the earth station system was the most reliable with a ten-year MTBF. This was because the system reliability increased with decreasing system failure rates. From Figures 7-9, the 2-parallel, 3-parallel, and 4-parallel configurations of the first system operational year reliability values were 0.90, 0.98, and 0.98, respectively. The values drastically decreased when the service of the satellite year has reached the tenth year, with reliability values of 0.24, 0.62, and 0.89, respectively. These numbers made up nearly half of the system reliability because the entire system functionality would undergo an increase in failure rates due to wear and tear all over the years until the lifespan ends. More redundancies in the system have shown to increase its reliability in the first year of operation. As a result, the 4-parallel design of the earth station system was more reliable than the rest. However, was this the right configuration to be opted in the earth station system design? Logically, more redundant units mean additional money needs to be spent. The sustainable framework in this research referred to the acceptable system reliability with less cost consumption and new maintenance activities to be proposed. Therefore, the most suitable configuration that met the criteria was chosen for the earth station system design.

4.1. Affordability profile of the earth station system

From the simulation, the cost of failures could also be calculated throughout its lifespan by applying (8) and the result is tabulated in Table 1. The second year of each parallel configuration faced high-cost consumption than the first year as the system stabilised through frequent failures. The cost consumed was also observed to increase each year as the system was more prone to failure, especially when the system reliability decreased. As a result, the 2-parallel, 3-parallel, and 4-parallel configurations were estimated to consume 2.009B$, 2.735B$, and 2.017B$, respectively throughout the earth station system lifecycle. Among all the three configurations, the three redundancies were the most expensive one in comparison to two redundancies and four redundancies. It is because the 4-parallel configured system would consume lesser maintenance cost as the redundant units act as the backup for faulty any subsystem. The faulty subsystem is not necessarily needed to be sent for repair. Whereas the four redundancies were the second highest expensive and the two redundancies were the cheapest among the three. Therefore, it can be proven that the earth station system with two redundancies yielded smaller operational cost consumption despite providing the lowest reliability rate amongst others with an acceptable reliability value. With its low maintenance cost to operate each subsystem throughout the lifespan, the 2-parallel configuration of the earth station system design was selected for the development of a sustainable framework.

Table 1. The affordability profile of each configurations throughout its lifespan

Parallel configuration	Cost consumed by year (e^{10} \$)				
	1	2	3	4	5
2-parallel configuration	0.004	1.177	6.936	16.714	16.097
3-parallel configuration	0.004	1.650	11.420	20.383	18.705
4-parallel configuration	0.004	1.470	11.416	20.380	29.757
	6	7	8	9	10
2-parallel configuration	21.024	31.851	33.342	32.894	40.857
3-parallel configuration	17.516	41.051	47.392	51.147	64.300
4-parallel configuration	40.560	10.323	30.610	20.561	36.633

4.2. Development of the reliability and the operational cost models of the earth station system design

In this section, the development of the reliability and the operational cost models are discussed. The 2-parallel configuration with a 10-year MTBF of an earth station system was chosen as the most ideal design to provide an optimum reliable performance within reasonable range of cost. As illustrated in Figure 10, a new simple but robust reliability model is shown in (9).

$$y = 1.1393e^{-0.122x} \tag{9}$$

Meanwhile, in Figure 11, a new simple but robust operational cost model was also developed and is shown in (10).

$$y = 4.6792x - 5.6464 \tag{10}$$

The reliability model was generated exponentially based on the values of ten-year MTBF 2-parallel configuration with a minimal range of error percentage of less than 9%. A linear relationship was generated from the values of a similar earth station configuration for its operational cost model with an acceptable margin of error. This was due to the exponential graph generated from the cost value that resulted in high error percentage.

Then, these reliability and operational cost model values were compared with the models that were previously generated by [4] and [28] in Table 2 for validation. The calculated RMS value for the newly generated reliability model was 20.84%, whereas the RMS value for the operational cost model was 22.82%. These values were within the acceptable range. Therefore, it can be concluded that the new reliability and operational cost models were verified to be used in the earth station system design.

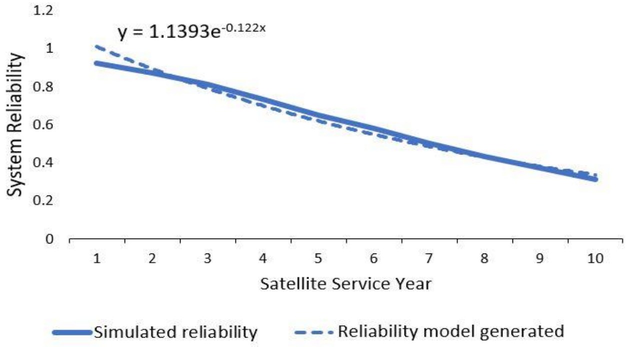

Figure 10. Reliability graph of 2-parallel configuration with a 10-year MTBF earth station configuration model against the measured curve

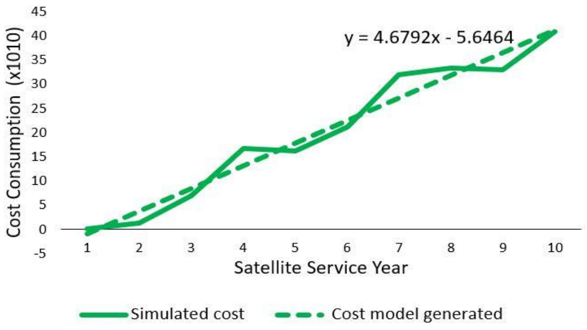

Figure 11. Operational cost graph of 2-parallel configuration with 10-year MTBF earth station configuration model against the measured curve

Table 2. The models validation

Earth station service year	Reliability model		Percentage error (%)	Cost model (x e10)		Percentage error (%)
	New	Abdul Rahim	New/Abdul Rahim	New	Amaitik	New/Amaitik
1	1.01	0.93	-8.60	0.97	0.00	-247.00
2	0.89	0.9	1.11	3.71	7.23	48.67
3	0.79	0.87	9.20	8.39	9.07	7.47
4	0.7	0.84	16.67	13.07	17.16	23.81
5	0.62	0.8	22.50	17.75	16.57	-7.10
6	0.55	0.77	28.57	22.43	21.65	-3.58
7	0.49	0.74	33.78	27.11	25.57	-6.03
8	0.43	0.71	39.44	31.79	34.36	7.50
9	0.38	0.68	44.12	36.47	39.62	7.96
10	0.34	0.64	46.88	41.15	41.95	1.92
			RMS Value= 20.84			RMS Value= 22.82

4.3. Proposed maintenance activities

The list of factors that must be considered in selecting the optimum maintenance activities for the earth station system was identified in order to ensure that it functions sustainably. Based on the typical problems reported generally, Table 3 lists the recommended maintenance activities. The optimal maintenance tasks for the specified equipment are often determined by the state of the subsystem. The mentioned maintenance tasks must be completed on a regular basis, and the replacement part is only done when the subsystem has stopped functioning.

Table 3. The proposed maintenance activities

Equipment	Maintenance activity	Potential fault
High power amplifier (HPA)	1. Clean Air In/Out filter. 2. Check RF output from monitoring port and compare spectrum plot with previous activity. This is to check whether current attenuation/gain of the HPA is okay or not. 3. Verify the front panel using local control (panel button) and remote control (M&C System).	1. HPA blower fault due to air inlet sensor problem or mechanical blower problem. 2. Klystron amplifier due to unsuitable current supply, channel switch problem and connectivity port issue.
Up-converter (UC) and down-converter (DC)	1. Blow or vacuum the dust spot on the unit. 2. Verify and tighten power cables and RF in/out cables. 3. Check RF output from monitoring port and adjust attenuation/gain value if required.	1. Power supply module faulty probably due to short circuit. Replace with new module. 2. Unit has low gain parameter probably due to unit ageing factor. Replace with new gain module or new unit.
Low-noise amplifier (LNA)	1. Check the physical unit inside antenna hub. 2. Make sure online unit has no latched fault shown on LNA Controller panel or M&C page. 3. Perform LNA current(mA) calibration if required.	1. The current(mA) exceeded the calibrated current and result to unit faulty. 2. Lightning hit the antenna and caused high current flow to LNA.
Antenna	1. Annual antenna dish cleaning. 2. Annual antenna motor greasing/oiling. 3. Verify antenna control unit (ACU). Make sure correct parameter has been keyed-in for satellite tracking. 4. Check the condition of feed and Teflon and make sure the air pressure inside feed is good or not. 5. Clean the antenna hub.	1. Broken antenna motor gearbox. 2. Broken elevation/azimuth jackscrew. 3. ACU power module fault. 4. Low air pressure inside waveguide system and antenna feed. Need to check the dehydrator system.
Measurement and control system (M&C system)	1. Make sure all RF equipment status reflect on the M&C page. 2. Make sure the M&C license is renewed and audited. 3. Check the physical M&C unit.	1. M&C unit power supply faulty. 2. M&C unit ports unresponsive/faulty.
RF backup unit	1. Physical inspection. 2. Verify the unit by injecting clean wave (CW) and measure the output. 3. Make sure no alarm shown on the front panel.	1. Possible faulty alarm or equipment.

5. CONCLUSION AND FUTURE WORK

In conclusion, reliability, cost, and maintainability have been endorsed as the three key components in the framework of this research for a sustainable earth station system design. The system reliability of an optimum MTBF value is achieved through the integration of redundancies, selection of only the best components for its subsystems and extensive testing during the planning stage. This is crucial to avoid any unexpected failures. Therefore, it is vital to develop a reliability model to calculate the likelihood that an earth station system must operate within a specific time frame. The programming tool that was used in this research is MATLAB. Additionally, appropriate frequent maintenance procedures play a crucial role. Corrective and preventative maintenance must be carefully planned and relevant to the most recent technological requirements. The design choices also have an impact on how cost-effective the system is over its whole lifespan. The main research contribution is the development of a sustainable framework which comprises the reliability and operational cost models along with suitable maintenance activities. Moreover, three types of parallel configurations of the earth station design were compared comprising 2,3 and 4-parallel configurations. From this comparison, an earth station design with 2-parallel configuration yielded the lowest cost consumption with an optimum reliability. Hence, the sustainable framework was modelled based on an earth station design with 2-parallel configuration. This paper also showed computation of the percentage fractional error and RMS error for both reliability and operational cost models. From these calculations, one can decide which model gives the smallest RMS error to develop the suitable reliability and cost models. The computed RMS value for the new reliability model provided the smallest value of 20.84%, whereas the generated operational cost model also provided the smallest value of 22.82%. This research can then be improved by implementing AI that is proven to get further smallest RMS error, which is useful in modelling both reliability and cost models.

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