The Maintenance of KSA-CORS Network in Saudi Arabia's Desert Areas

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Key words: KSA-CORS network, CORS Operation, CORS Maintenance, CORS Desert Maintenance Challenges.

SUMMARY

Saudi Arabia is a large arid country, covering more than 2 million square kilometers of desert and remote areas. Part of the kingdom's popular desert is the Empty Quarter in the south-eastern part of the Kingdom. Maintaining a CORS network in these challenging conditions is not easy task. This paper shares the Saudi Arabia experience with the issues faced in the preventive and corrective maintenance of the KSA-CORS network, particularly in the harsh desert environments. The paper also suggests strategies to improve maintenance management and ensure the long-term sustainability of the operation in these difficult environments.

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1. INTRODUCTION

The importance of Continuously Operating Reference Stations (CORS) in modern geodesy and navigation is undisputed. In Saudi Arabia, the KSA-CORS network constitutes an essential infrastructure for a wide range of applications, from land surveying, autonomous navigation, infrastructure monitoring to atmospheric sciences. However, the task of maintaining this crucial network in the desert and isolated regions presents alarming challenges.
In the kingdom lies the Rub' Al Khali, also known as Empty Quarter. This desert is the world's biggest continuous sand desert. Spanning an estimated area of 640,000 square kilometers in southeastern Saudi Arabia as reported by Saudi General Authority for Statistics (2015). The Figure 1 shows the map of KSA-CORS network in Saudi Arabia.

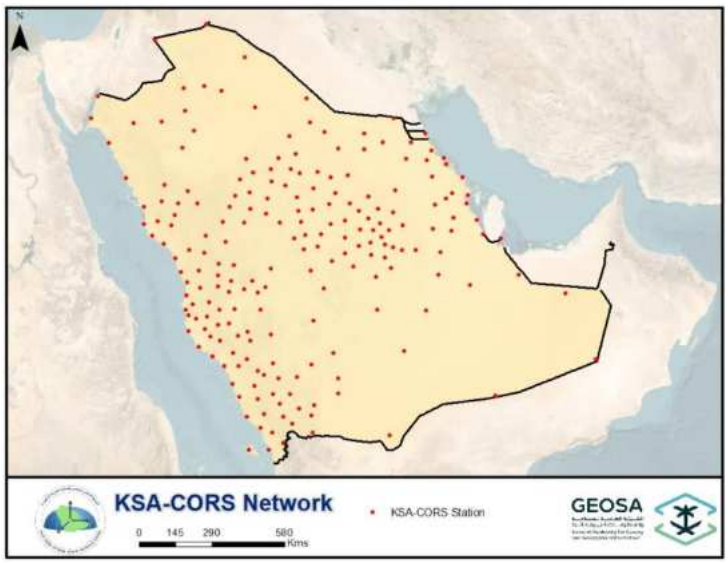

Figure 1: Active KSA-CORS Network

The harsh conditions and inaccessible nature of Saudi Arabia's desert regions create specific maintenance challenges for the KSA-CORS network. These challenges include severe heat, constantly moving sand dunes, ensuring consistent GNSS data transmission, maintaining equipment functionality in extreme temperatures, lack of conventional infrastructure affecting

remote CORS access. The desert landscapes are not merely geographic obstacles, they serve as platform for evaluating the robustness and adaptability of geodetic infrastructure.
Managing KSA-CORS networks in such an environment requires tackling various operational and maintenance challenges. These challenges include increased degradation of equipment caused by dust and heat exposure, to the complexities of deploying and supporting technical maintenance personnel in remote locations, frequently accessible through challenging paths. The reliability of KSA-CORS stations is crucial in these areas, as any interruptions or incorrect information could have significant consequences for the multitude of user applications and the maintenance of the national geodetic reference frame. The operational challenges are further heightened by the need for consistent calibration, software updates, and hardware repairs, all of which must be conducted around one of the most challenging environments on the planet. This paper explores the KSA-CORS network within the vast and remote desert areas of the kingdom. It also provides insights into strategies used to overcome these challenges. The discussions and conclusions drawn offer guidance for CORS network management in severe conditions and contribute to the global understanding of geodetic infrastructure maintenance strategies.

2. MOTIVATION

The launching of large-scale projects in Saudi Arabia calls for the expansion of KSA-CORS into extremely challenging terrains. The CORS network is pivotal for real-time corrections in surveying and navigation (Schrock 2016), its extension into the expansive desert region is primarily to support the recent surge in mega and giga projects in the kingdom.
The kingdom's deserts are some of the most inhospitable places for technological infrastructure due to their harsh conditions. Intense heat in the summer and cold temperatures during the winter, coupled with frequent sandstorms, create a challenging environment for the KSA-CORS network operations. This environment is highly demanding, leading to rapid wear and tear on remote stations, all of which necessitates increased network maintenance. The GNSS-CORS problems, however, are not exclusive to Saudi Arabia. Network operators worldwide face CORS maintenance problems. Studies such as one by Janssen et al. 2011 in New South Wales, Australia, have reported CORS challenges that includes equipment failure due to environmental factors, data transmission reliability, and the need for regular calibration and maintenance. Further studies, like that conducted by Fernandes et al. 2013 provided insight into the complexities of maintaining critical geodetic infrastructures. The authors reported the issues concerning GNSS data transfer and monitoring, access to reliable grid power, internet access and the security of the GNSS CORS was also a major concern. However, the desert areas of Saudi Arabia's offer a unique case study and insights can be gained by looking at how regions manage similar challenges. to the Saudi context. However, a significant gap is evident in the

literature that specifically addresses the distinct challenges presented by extreme desert conditions. This gap highlights the importance of this study.

3. OPERATIONAL AND MAINTENANCE CHALLENGES OF KSA-CORS IN THE DESERT

This section outlines the KSA-CORS challenges, focusing on the limitations of terrestrial communication links, the implications of sandstorms, and the logistical constraints faced in desert environments.

3.1. Terrestrial Communication Links Challenges

Desert-based KSA-CORS often suffer from unreliable terrestrial communication links, leading KSA-CORS stations to primarily depend on satellite communication (V-SAT) solution. Despite its practicality, V-SAT is not without drawbacks, notably its higher latency compared to terrestrial communication. Weather events severely disrupt V-SAT links, leading to increased latency and connectivity issues especially during the recovery of missing data epochs via FTP following network disruptions. Frequent V-SAT communication problems necessitate coordination with satellite communication service providers for maintenance scheduling adjustments. When the KSA-CORS experiences regular issues with V-SAT communication, the operation team coordinates with satellite communication vendors to resolve the problem. Unpredictable communication problems often lead to the rescheduling of maintenance visits depending on the weather condition.

3.2. Effect of Sandstorms on KSA-CORS

In the context of KSA-CORS stations located in desert environments, sandstorms present a significant challenge to maintaining operational integrity. These natural phenomena interfere with GNSS signal reception and real-time monitoring of data streams, particularly impacting V-SAT communications due to their sensitivity to environmental conditions. Over time, sandstorms also have a detrimental effect on the essential equipment within KSA-CORS enclosure cabinets. Devices such as routers and other sensitive instruments are at risk of malfunction, including hanging or burning out, attributed to the severe environmental conditions and extended operational durations. Furthermore, the presence of dust and sand particles in these storms poses a direct threat to the physical integrity of these equipment. The infiltration of dust can lead to damage in critical components and compromise the effectiveness of cooling and ventilation systems, ultimately resulting in overheating. illustrates a typical scenario in the area, where dust has penetrated an IP66-rated dust and waterproof CORS cabinet enclosure, underscoring the severity of the issue. The accumulation of dust in cabinet cooling

system filters is particularly problematic, leading to clogging that diminishes their effectiveness and heightens the risk of equipment overheating.

Figure 2: : KSA-CORS IP66 Internal Cabinet filled with Dust

Additionally, the reliance on solar panels as a power source in areas without grid connectivity poses further challenges. One such issue is the frequent build-up of dust on solar panels, which significantly reduces their efficiency. Moreover, there are instances where the solar controller fails to charge the batteries sufficiently for the next operational cycle, further complicating maintenance efforts.

3.3 Accessibility and Logistics

The establishment of KSA-CORS in the remote desert regions of Saudi Arabia demands tailored logistical planning. To access these sites for corrective or preventive maintenance, vehicles equipped with 4x4 engines are essential for handling the demanding off-road conditions, along with drivers skilled in desert navigation. The lack of basic facilities like hotels and gas stations in the extreme desert areas like Rub' Al Khali further complicates logistics. As a result, field technical crews are often required to travel extensive distances to reach the stations or alternatively opt for camping in the vicinity, which adds to the operational hurdles. For communication with the network data center team, the field maintenance team primarily relies on satellite phones since terrestiral communication is not available along the routes. This mode of communication necessitates concise and strategic coordination, as real-time continuous communication is not always possible. An example of the challenges faced is

depicted in Figure 3, showing a KSA-CORS field maintenance team truck stranded in the desert.

Figure 3: Field Maintenance Crew 4x4 Truck stuck in the desert above 45°

3.4. Power Supply Challenges

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At KSA-CORS stations located in desert regions, the efficiency of solar panels is often undermined by the accumulation of dust, a prevalent issue in such environments. In addition, the solar controller frequently experiences malfunctions that hinder its capacity to sufficiently charge batteries for upcoming operational cycles, representing a recurrent challenge in maintaining a reliable power supply.

3.5. Absence of Air Conditioning in Stations

In the far desert regions, KSA-CORS stations are confronted with the significant challenge of not having air conditioning systems. This is especially problematic given the high temperatures typically encountered in the desert. The primary reason for this absence is the limitations of solar panels, which are the prevalent power source for stations in the desert areas. These solar panels are incapable of generating the necessary energy to operate air conditioning units. Consequently, this leads to a reduced lifespan for batteries and overheating of equipment, thereby exacerbating maintenance and operational difficulties.

The remote nature of these stations necessitates advanced monitoring and control systems. Network management, data analysis, and troubleshooting require sophisticated software

solutions. The integration of automated systems and AI-driven technologies can significantly enhance predictive maintenance and anomaly detection, ensuring more efficient data management. However, the adoption of such technologies brings its own set of complexities, including the need for a workforce skilled in modern operational technology systems for remote monitoring, in addition to expertise in geodesy and IT communication.

3.6. KSA-CORS Maintenance Tickets

The maintenance ticketing system for the KSA-CORS network provides an extensive overview of the maintenance tasks undertaken. This system captures a wide range of data, including ticket types, initial station statuses, problem categories, and final outcomes. This comprehensive dataset enables a detailed examination of the most common maintenance issues and the effectiveness of the solutions implemented. An initial analysis of the KSA-CORS maintenance records highlights key challenges. A considerable number of tickets are marked "VSAT Down," indicating frequent communication disruptions within the desert CORS. This highlights the need for robust communication systems, especially in remote and challenging environments. The second most widespread problem reported is power outage, emphasizing the criticality of dependable power sources in remote and harsh conditions. Another set of problems includes technical equipment failures and malfunctions. This category encompasses problems such as "Battery running low" and "Router hanging," reflecting the difficulties of maintaining sensitive equipment in extreme temperatures and sand-prone areas. Issues like the hanging of cabinet enclosure equipment, including routers and GNSS receivers, are also prevalent. These problems point to the operational challenges posed by the harsh environmental conditions. This analysis underscores the need for effective strategies to address the unique maintenance challenges of KSA-CORS stations, particularly those in remote desert locations.

4. IMPLEMENTED STRATEGIES FOR ENHANCING KSA-CORS NETWORK IN THE DESEART AREA

This section highlights the strategies implemented to address the challenges faced in section three of this paper. The approach involves integration of technology and careful planning to overcome the challenges encountered around these areas.

4.1 Advanced Technical Implementations

In response to the equipment malfunction issues caused by extreme temperatures, the KSA-CORS network has introduced industrial rugged model communication routers. These routers are designed to withstand temperatures up to 70 degrees Celsius, significantly enhancing their

reliability in harsh desert conditions. Additionally, a sophisticated GeoSCADA system has been established at the operation center in Riyadh. This system is connected to Programmable Logic Controller (PLC) components at the remote CORS stations, which are of a hardened, ruggedized model to ensure durability. Similarly, W.H. Ip et al. (2000) proposed a set of maintenance strategies and a computerized Supervisory Control and Data Acquisition (SCADA) system for achieving an integrated maintenance management system. This approach aims to improve overall equipment effectiveness and reduce downtime. The authors use real-time and historical data to measure, visualize and quantify the progress of maintenance activities.

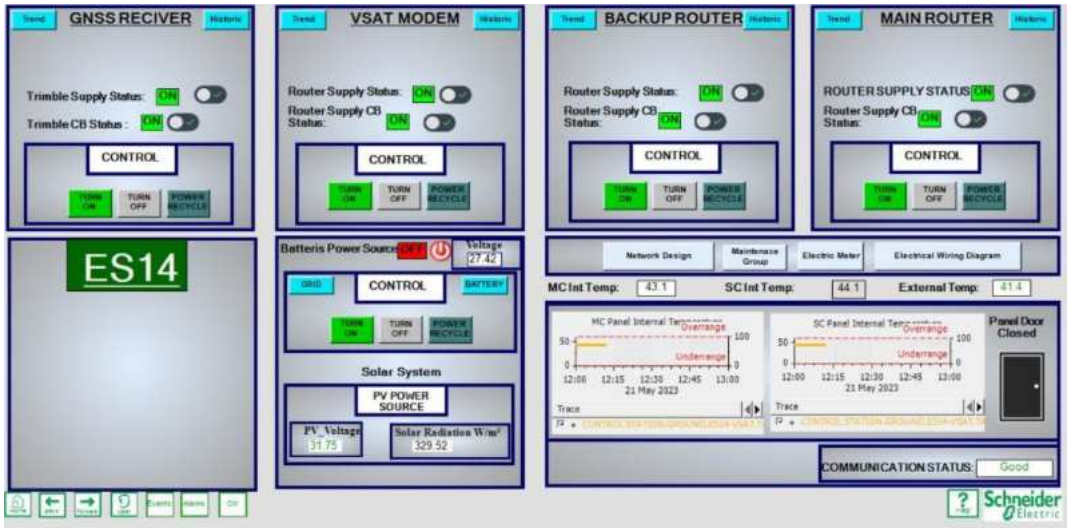

Figure 4: GeoSCADA monitoring for KSA-CORS

The PLC components, capable of enduring temperatures up to 70 degrees Celsius, play a vital role in monitoring essential parameters of the CORS cabinet. They are responsible for overseeing the voltage levels of batteries, main and backup routers, as well as GNSS receivers. These components also have the functionality to control the switching on and off of these devices. Additionally, they measure both the internal and external temperatures of the cabinets. A key component in this system is the Schneider M340 PLC, acting as an executor of all GeoSCADA commands. Crucially, the PLC transmits alarm data via a backup router, ensuring the uninterrupted flow of the GNSS data stream through the main router. This advanced integration marks a strategic transition towards more sophisticated and remotely controlled operational frameworks, keeping pace with the latest developments in geospatial technologies.

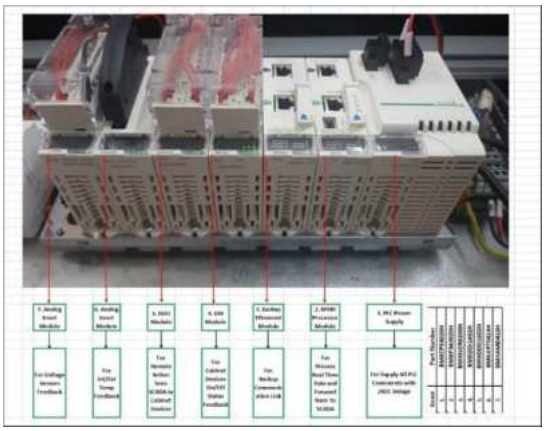

Figure 5: Functionalities of all KSA-CORS PLC Components

4.2 Enhanced Infrastructure Design

To address the impact of high temperatures, especially considering the lack of air conditioning systems at desert KSA-CORS, a dual cabinet approach has been implemented. This strategy involves deploying two cabinets for the desert CORS station to distribute and lessen the load within each enclosure cabinet, effectively reducing the overall temperature. Additionally, high-temperature batteries have been integrated. These batteries are impervious to heat and boast an extended design life of eight years, with an operational tolerance of up to 65 degrees Celsius. In a further effort to monitor environmental conditions, photovoltaic cell pyranometers have been installed to measure solar radiations accurately through the GeoSCADA system at the data center. A crucial innovation is the addition of a galvanized sheet metal layer to the main enclosure cabinet. This layer acts as a protective shield for the equipment, akin to how sunglasses protect one's eyes from intense sunlight. By reflecting the sun's rays and minimizing direct heat exposure, this cabinet shield effectively controls temperature rises within the cabinet. This adaptation is particularly vital in compensating for the absence of air conditioning in desert CORS stations, ensuring both the longevity and reliability of the equipment housed within. Figure 6 illustrates this protective layer in action.

Figure 6: KSA-CORS Cabinet protective layer

4.3. Strategic Monumentation Design

The design and monumentation of CORS stations within the desert have been carefully established to withstand high sandstorm conditions. Particular attention is paid to the elevation of each site, ensuring that the CORS base and cabinet remain above sand levels during storms. Figure 7 depicts the CORS site ES12, situated near Shaybah, about 40 kilometers from the northern border of the Rub' Al Khali desert.

Figure 7: KSA-CORS High Monumnetation Base at the northern edge of Rub' Al Khali

4.4 Preventive Measures and Logistical Planning

To enhance responsiveness, field teams have been stationed in towns closest to these areas. Key preventive strategies include keeping a stock of crucial spare parts to reduce downtime

significantly. The planning of preventive maintenance trips is meticulous, taking into account travel durations, accommodation limitations, and potential delays. Additionally, contingency plans are established to handle unexpected equipment failures swiftly and effectively. Each team is equiped with satellite phone for communication.

Figure 8: KSA-CORS around the coastal area

4.5 Team Training and Support

Field maintenance teams are not only equipped with specialized off-road vehicles but are also thoroughly trained in desert navigation and survival techniques. To ensure rapid response and support during emergencies, backup teams are maintained on standby, ready to assist in both preventive and corrective field operations. This comprehensive training and support structure is integral to maintaining the operational efficiency and safety of the teams working in these challenging environments.

4.6. Continuous Monitoring and Improvement

The remote monitoring capabilities for KSA-CORS stations in desert regions are crucial for the early identification of issues, thereby reducing the frequency of corrective maintenance visits. Feedback from field teams has proven invaluable for the continuous refinement and improvement of maintenance strategies and protocols. Figure 9 illustrates the KSA-CORS Operation and Monitoring Center located within the General Authority for Survey and Geospatial Information production building.

Figure 9: KSA-CORS Network Operation & Monitoring Center

In addition, the center employs PRTG, developed by Paessler AG, for continuous real-time monitoring of both primary and backup communication links. The PRTG is shown in the first screen from the left in Figure 8. This system provides instant data on their operational status, including bandwidth usage, outage detection, slowdown identification, and abnormal traffic pattern analysis. With immediate access to this information, network operators can rapidly address issues, thereby minimizing downtime. The operation team also identifies peak usage times, bandwidth hogs, and potential bottlenecks, which assists in planning network capacity and future upgrades. The second screen from the left shows the health status of KSA-CORS. The third screen is the GEOSCADA alarm monitoring system.

5. CONCLUTION

This paper describes the CORS stations maintenance challenging in Saudi Arabia desert environments and the need for innovative, coordinated strategies for improvement. The experiences gained and the approaches developed offer valuable lessons not only for the upkeep of KSA-CORS but also for other critical infrastructures situated in similarly demanding conditions. The effective management of these stations, particularly those in the desert, exemplifies a model of technological and operational resilience.

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BIOGRAPHICAL NOTES

Eng. Saad Al-Qahtani

An accomplished department manager who has spent over 10 years in the field of Geomatics and Geodesy. He received his bachelor's degree in Survey Engineering from King Saud University and later went to earn his master's degree in Geospatial information science from the University of Flinders. He currently manages the CORS department from the General Directorate of Geodesy at GEOSA. He is passionate about geospatial technology.

Eng. Abdulwasiu Salawu

Holds a bachelor's degree in Environmental Engineering, a master's in Geoinformatics and an MBA. As a graduate member of the Nigeria Society of Engineers, his experience spans both private and government sectors, working in construction, geodesy, land survey, hydrography, and business analysis. Presently, he serves as a Geodetic Consultant for the KSA-CORS network at GEOSA in Riyadh, where he employs his expertise in geospatial technology. His passion lies in pioneering new geospatial ventures and formulating business strategies, aiming to empower organizations to harness the benefits of geospatial technology for commercial success.

Eng. Meshari Al-Shahrani

He holds a Bachelor of Electrical Engineering and a master's degree in engineering management. He currently serves as the section head for KSA-CORS maintenance section. He also represents the CORS department at the Project Management Directorate of GEOSA. He is

responsible for the field maintenance teams, corrective and preventive maintenance of KSA-CORS network.

Eng. Abdullah Al-Thawwad
Hold a bachelor's degree in Survey Engineering from King Saud University in Riyadh. He worked in the construction industry prior to joining GEOSA. He currently heads the KSA-CORS network Operations session where he is responsible for overseeing the daily operations of KSA-CORS business at the data center.

Eng. Abdullah Al-Qahtani
Serving as the director of the Executive Directorate of Geodesy at GEOSA, he holds a degree in Survey Engineering from King Saud University and a master's in Geospatial Engineering from the University of New South Wales. His responsibilities include managing the departments of CORS, Vertical Network and Spatial Reference Systems. He also lead the development of the Saudi Arabian National Spatial Reference System (SANSRS). Additional, he represents Saudi Arabia in the International Organization for Standardization (ISO) geodetic registries' Consultation Group and the Sub Committee of Geodesy (SCoG) under the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM).

Eng. Othman Al-Kherayef
Curently hold the position of an advicer the President of GEOSA. He is the GEOSA president for FIG. He Graduated from Survey Engineering from King Saud University in 1992. He attended Army Survey Course at the School of Military Survey in the United Kingdom in 1995. He has served in the General Department of Military Survey (GDMS) from 1993 until 2010. He also served as manager in different sections of GDMS. He also served as the director for geodesy directorate at the then General Commission for Survey. His research interest includes geodetic surveys and data processing.

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