Post Study Design of Wireless Network for the Water Dilemma in the city of Rujban

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Abstract— **Providing water for daily life usage is one of the biggest obstacles facing the growth and development of cities not only in Libya but in many countries of the world. The city of Rujban faces this crisis despite the passage of more than five decades in trying to resolve this issue. We did some deep research and study on the water system operation problem which we divided into three parts: Karthoom Automated Control System (KACS), Idref Automated Control System 1(IACS1), Idref Automated Control System 2 (IACS2) because water is pumped on 3 different stages. The IACS1 consists of two main parts: transmitter/collector tank on one side and receiver / pumps on the other side. The transmitter end consists of a microcontroller, three stage level sensor, two water flow sensors and an RF transmitter. The other end consists of two water pumping pump and an RF receiver. The system will be automated by the use of a microcontroller in which each level of the collector tank will be designed to turn on just one or both pumps of in the case there is certain amount of water, which can be determined by water level sensor, in Karthom collection tank. A crucial part of this coordination is the flow meter which will indicate if the pump is operational or not and detect whether or not there is water leakage, all of which will be demonstrated on an LCD screen. In this paper, we will design a wireless communication network for IACS1.**

Index Terms: **Wireless Network, Smart irrigation system, Water pumping**

I. INTRODUCTION

Water Management has been a universal dilemma; control of such a commodity has been the biggest concern. The city of Rujban suffers from this issue. The root of this problem can be traced to out dated 50-year-old systems which rely on human input. This motivated us to find possible solutions for such a matter

The lack of water availability as a result of bad manual operation of water pumping between the two big size reservoirs that are in Karthoum and Idrif is considered to be a problem that is elevating and rising, especially with the growth of the population in the city.

To develop root solutions for the above mentioned obstacles, we have designed an automatic system to control the flow of water from the collecting tank, which is located in the wells area to the other same-size collecting tank in Idrif through more than 30 km 12" water pipe lines.

Our system has the ability to determine the level of water in 3 levels and then make a decision of the number of pumps that must be operated accordingly and then sends an "on" signal through a designed wireless link to the pumping pumps that must be operated. Furthermore, the system has the ability to prioritize which of the pumps must be run automatically on the basis of the time worked by each pump to maintain the life of the pumps.

In addition, the system has the ability to sense the flow of water from the water pipe coming from the Karthoom tank and entering into the Idrif collecting tank. Whilst stopping in the case of running the pump, the IACS1 sends an "off" signal through a wireless link to the pump to automatically turn it off. Furthermore, the IACS1 has the ability to clarify the presence of leakage of pipes or the weakness of the pumping pump through water flowing sensors.

The system displays all cases such as pumps that are operational and nonoperational as well as their times and it displays the level of water in the collecting tank and can give warnings in some cases, such as the suspension of a number of pumps or the existence of some disruptions in the pipes

After determining running the pump or stopping it, the system sends an "on or off" signal to the pump that must be operated or stopped from operating through an RF signal. The transmitter can transmit to the operator with the directional antennae. As for the receiver at the other end, it can receive signals sent by the transmitter and pass them to a certain pump by a specific code using ZigBee technology.

Section II provides a review of existing efforts and works related to the topic at hand. In Section III, the problem statement is presented. With the problem clearly stated, section IV proposes the methods of solutions for the problem. The described methods were incrementally-designed for this work and are presented in such fashion to illustrate the layers of the work. Section V discusses the simulation that was designed to prove the concepts of the designed methods based upon the problem statement and assumptions previously detailed. It describes the design, operation, and gathered results of the simulation software. Section VI discusses the conclusion and presents a narrow necessary future work.

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II. LITERATURE REVIEW

In order to understand the nature of this paper, it is important to review related work. In addition to problem studying, there are two main contextual areas of focus in this work: wireless networks (WNs), and control system. While the primary focus of the paper is in the area of WNs, important consideration needs to be given to another area.

There are many existing technologies and a variety of approaches in the field of WSNs regarding outdoor applications but we depend mostly on the reference (book) and radio mobile information.

Ritesh Boda (2016) designed and developed a smart wireless technology using microcontroller for agricultural various crops with irrigation system. He uses Zigbee wireless control system to provide a smart irrigation system which provides efficient water supply for the farm; that saves water and reduces the manpower for irrigation.

Khaled Reza el al., (2010) introduced the concept of water level monitoring and management. His research result was an economical system designed on a low cost PIC16F84A microcontroller; and proposed a web and cellular based monitoring service protocol to determine and senses water level globally.

Rojiha (2013) analyzed the existing oil-pumping system and discovered that it has a high power-consuming process and should entail more manual power. He proposed a sensor network based intelligent control system for saving power and efficient monitoring of oil well health. If any abnormality is detected in the oil well data sensing, then the maintenance manager is notified through an sms via the GSM. This system allowed oil wells to be monitored from remote places.

Sudip Dogra (2015) designed a system to help people living in multi storied buildings who face inconvenience when there is shortage of water in the tank. This system automatically pumps water from the reservoir to the tank whenever the level of water decreases which is checked using a Ping sensor that is connected to a stamp microcontroller with the aim of switching on the pump as soon as it is empty.

III. PROBLEM FORMULATION

To clear up the water issues in a comprehensible manner, this section has been further divided to two sections: water infrastructure and water system operation.

A. Water Infrastructure

In the 1960s, the state under took the following measures:

- Dug four wells at depths of more than 500 meters in the Kartˡum area, which is more than 25 km away from the present city center
- Built a ground collection tank which was receiving water from wells through special pipes.
- Provided huge power generators to supply the necessary power to feed the pumping pumps, which pump water from the collection tank in the wells area to the upper distribution tank located in the current city center.
- Construction of a number of essential buildings represented in the pumping station building and the housing building in the main station and small buildings next to each of the wells used in which to put generators and for guarding purposes
- Connected the water pipeline to an upper distribution tank in the idref area (Rujban current center) from which water lines are transferred to all the villages located at the foot of the mountain
- provided public faucets in each village at the time.

Then, in the early seventies, the state connected a special power line to the water station in Karthum and dug a number of other wells in order to increase water productivity; also internal village distribution networks were built. During this period, water was pumped periodically (a day per week) and this was the best period for the city's water situation.

In the nineties of the last century and the beginning of the first century of the current decade, the state sought to develop the water scheme in the city so it has established several facilities, including two huge reservoirs for the collection of water, each with the capacity of 120000m3 one of them in Karthoom and the other one in the modern city center next to the former distribution tank. As well as the construction of two pumping stations adjacent to the collection tanks. A new 30 km pipeline has also been constructed between the collection tanks.

A new distribution network was built to and in villages but unfortunately it has not been used to this day. In addition, 3 distribution tanks were constructed with the height of 25 meters and the implementation of a water pipeline between it and the collection tank.

In recent years, the city officials have tried to supplement the water projects and address the reasons for its non-availability; this work is currently underway to completion such as restoring the existing networks and leakages in tanks, etc.

Five additional distribution tanks have been contracted to be built by the state and an internal network for the villages has been designed for submission to the private entities of the State.

B. Operation

Despite the numerous amounts spent by the state on this problem, our city still faces a major crisis by not having enough water provided for daily use. After an in-depth study of this problem it became clear that:

- Manual operation of submersible pumps for wells and its remoteness from the main station where the distance is sometimes greater than 3 kilometers.
- Lack of high-level water monitoring in the collection tank.
- Lack of means of transportation and difficulty in moving from the station to wells.
- Power cuts from time to time and the consequent stop of water pumping and being obliged to go operate it.
- Lack of knowledge of water interruption.

• High labor prices.

The main motive for conducting this study and suggesting possible economic solutions is to solve this problem and to promote the city, especially since the bulk of the expenses necessary to provide water at least with high distribution tanks near the residential communities have been paid. We can divide the problem into several parts a, b, c:

a) Pumping the water from the producing wells into the collection tank in the Karthoum area which is another research topic.

b) Pumping water from the assembly tank to the collection tank located in the Rujban center will be the topic of this paper.

c) Pumping water from the Rujban center collection tank to the upper distribution tanks and good management will therefore be dealt with in another paper.

IV. DESIGN AND DEVELOPMENT

Due to the magnitude, we divided this system (IACS1) into two parts, the first part is related to wireless communication, which is the subject of this paper, the other is related to the control part, and it will be another research topic

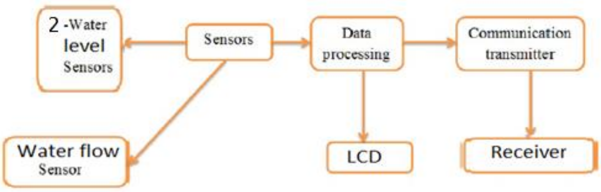


Figure 1. Block Diagram of the IACS1

A. *Design of Essential Wireless Network*

To design the system for pumping water from the collection tank in Karthoom to the collection tank in Idref, we need to design a wireless communication network that will transmit the operation and shutdown (on, off) signals based on the system's decision to examine the water level in the received water collecting tank or to examine the water flow sensation.

This network is in the form of point to point and can be designed with directional antennas, but due to the distance and the difficulty of the topography it is very difficult to achieve the constraint of direct vision that is needed for RF signals between the two connection points. We have to search to find other points that have antennas link and we have done many experiments to find the best of these points taking into account the need for a power source and having a building or any public facility for the connection antenna tower.

Therefore, the first successful approach is to use a public school in the village of Tebshan. and as a superior second proposal, we have chosen the distribution tank in the village of Aulad Jaber, because of the height of its ground elevation and the tank height itself, which can reduce the costs of building an antenna tower linkage as we will use this link for Aulad Jaber tank – Former distribution tank, to operate the IACS2 which will be the subject of the next research.

Due to the low location of the collection tank in the Idref area and the presence of an old high-rise distribution tank, we designed a link between the two tanks to minimize the cost of the transmitting antenna tower.

The area in which the wells and the station are located is open, but with somewhat desert like topography. It is important to first determine the ground elevation of each well and compare it to the ground elevation of the station and also determine the terrain separation between these two points(the station and the well) this is because RF signals need the presence of LOS between the two connection points (the transmitter and the receiver); we used Radio Mobile Frequency technology to determine the height of the transmitting antenna as well as receiving antennas each separately by using this available technique.

Free space path loss is a major issue when dealing with RF links in long distances, particularly outdoors. Typically, the device loses about 0.020 dB per foot in an outdoor or wide open office.

The relation between the transmit and receive power is given by Friis free space equations:

$$P_{RX\,(d)} = P_{TX}\, G_{TX}\, G_{RX} \left(\frac{\lambda}{4\pi d}\right)^2 \quad (1)$$

And it can be written as

$$P_{RX}|_{dBm} = P_{TX}|_{dBm} + G_{TX}|_{dB} + G_{RX}|_{dB} + 20\log\left(\frac{\lambda}{4\pi d}\right) \quad (2)$$

In a dual-polarized antenna, E- and H-planes represent the vertical and horizontal beam width respectively in degrees. The installation requirements determine the right beam width. In directional antennas, which has been used for our receivers, the H-planes are extremely small when the antenna gain is very high and that is true for E-planes too. Incorrect antenna height or alignment leads to poor RSSI values because the signal from transmitters antenna will be shot over or under the other antenna, so the RF installers must ensure that the antenna heights and alignment between endpoints are correct.

For successful transmission of RF signal between point to point links, a minimum unhindered path is required which means having a Fresnel zone that is divided into multiple zones when the maximum zone should not exceed 20% in zone one. RF LoS can be validated easily by monitoring the Received Signal Strength Indication (RSSI) value at the receiver. For point-to-point operation, it is better to choose a directional antenna that can operate in 5 GHz with 20 to 60 degrees in H-plane and 10 to 20 degrees in the E-plane. The difference between the power required for minimum acceptable performance and the normal received power is called the fade margin where greater fade margins mean fewer frequent occurrences of minimum performance levels and large fade margins mean that the received signal power during unfaded conditions is so strong that bit errors are practically absent. We used Radio Mobile Frequency technology to determine the height of the transmitting antenna as well as receiving antennas each separately by using this available technique.

B. Design of an Automatic Control System

This section will be the topic of next paper.

V. SIMULATION RESULTS

Although tabular results would have sufficed for proof of concept, we felt that detailed graphical results would much more effectively lend themselves to proper analysis and reveal characteristics specific to each method that might be left unnoticed in a tabular form. Thus, we created an automated graphing environment to effectively and efficiently display the encapsulated results of the result-gathering environment. The results of this effort are displayed liberally throughout this paper. Our simulation results are presented in the below figures. Each figure clearly illustrates the topography between the transmitter antenna and the receiving antenna for specified wells; the figures contain tables which show essential data determining hard ware parts needed for implementation.

The table is divided into 5 subsections in which the top two present data for latitude, longitude, ground elevation, antenna height, azimuth and tilt for the two end points (Transmitter/collector tank, and receiver/well). The next subsection illustrates information of the radio system which consists of transmitter- power, line loss and antenna gain and receiver- antenna gain, line loss and sensitivity. The fourth sub table gives information of propagation that shows free space, obstruction, forest, urban, statistical and total path losses. The last part of the table presents the performance, which includes distance, precision, frequency, equivalent isotropically radiated power, system gain, required reliability, received signal, and fade margin.

It has to be noticed that all heights of antennas are computed from ground elevation, so upon completion of the design, the antenna towers' heights should be equal to computed antenna height minus the building or tank height.

After many attempts, the first successful attempt is the connection among: Idrif work shop station / collector tank – former distribution tank – public school in tebshan – karthom work shop station. The below figures show the links layout and their simulation results.

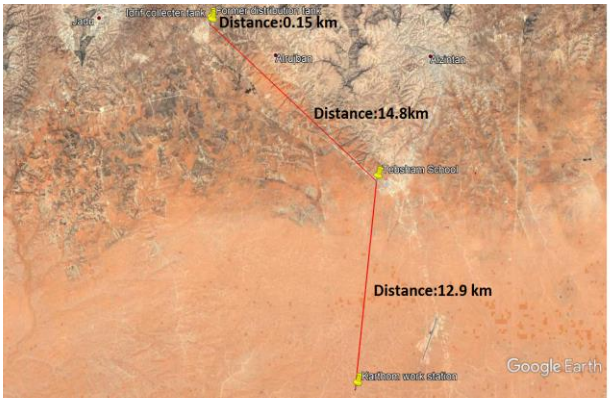
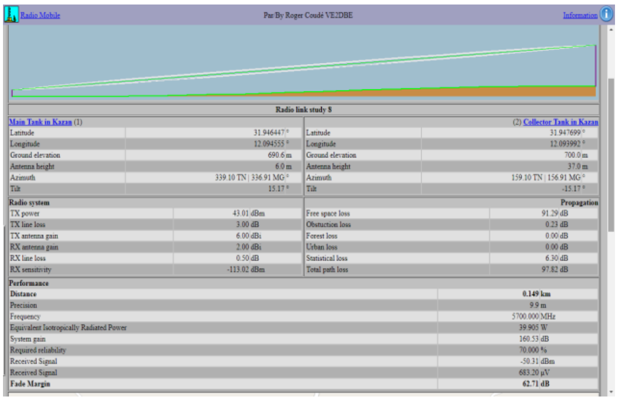


Figure 2. Links layout

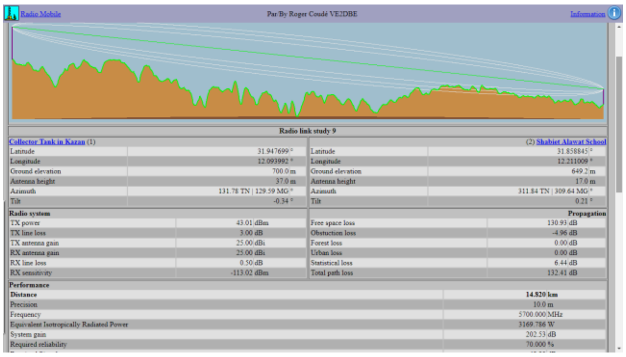
Although the distance between collector and former distribution tanks is just 149m the difference between their ground elevation is 9.4m. In addition, the height of the distribution tank which is about 20m, can be used for forward antenna. Thus, this is the first link that we've established to reduce the transmitter antenna tower cost.



Radio link study 8			
Main Tank in Kazan (1)		(2) Collector Tank in Kazan	
Latitude	31.946447 °	Latitude	31.947699 °
Longitude	12.094555 °	Longitude	12.093992 °
Ground elevation	690.6 m	Ground elevation	700.0 m
Antenna height	6.0 m	Antenna height	37.0 m
Azimuth	339.10 TN | 336.91 MG °	Azimuth	159.10 TN | 156.91 MG °
Tilt	15.17 °	Tilt	-15.17 °
Radio system			Propagation
TX power	43.01 dBm	Free space loss	91.29 dB
TX line loss	3.00 dB	Obstuction loss	0.23 dB
TX antenna gain	6.00 dBi	Forest loss	0.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	0.50 dB	Statistical loss	6.30 dB
RX sensitivity	-113.02 dBm	Total path loss	97.82 dB
Performance			
Distance			0.149 km
Precision			9.9 m
Frequency			5700.000 MHz
Equivalent Isotropically Radiated Power			39.905 W
System gain			160.53 dB
Required reliability			70.000 %
Received Signal			-50.31 dBm
Received Signal			683.20 µV
Fade Margin			62.71 dB

Figure 3. Layout for link 8

The reason for the antenna, which is located above former distribution tank in Idrif, being higher than it's supposed to be is because it has to achieve LoS with the other links.



Radio link study 9			
Collector Tank in Kazan (1)		(2) Shabiet Alawat School	
Latitude	31.947699 °	Latitude	31.858845 °
Longitude	12.093992 °	Longitude	12.211009 °
Ground elevation	700.0 m	Ground elevation	649.2 m
Antenna height	37.0 m	Antenna height	17.0 m
Azimuth	131.78 TN | 129.59 MG °	Azimuth	311.84 TN | 309.64 MG °
Tilt	-0.34 °	Tilt	0.21 °
Radio system			Propagation
TX power	43.01 dBm	Free space loss	130.93 dB
TX line loss	3.00 dB	Obstuction loss	-4.96 dB
TX antenna gain	25.00 dBi	Forest loss	0.00 dB
RX antenna gain	25.00 dBi	Urban loss	0.00 dB
RX line loss	0.50 dB	Statistical loss	6.44 dB
RX sensitivity	-113.02 dBm	Total path loss	132.41 dB
Performance			
Distance			14.820 km
Precision			10.0 m
Frequency			5700.000 MHz
Equivalent Isotropically Radiated Power			3169.786 W
System gain			202.53 dB
Required reliability			70.000 %

Figure 4. Layout for link 9

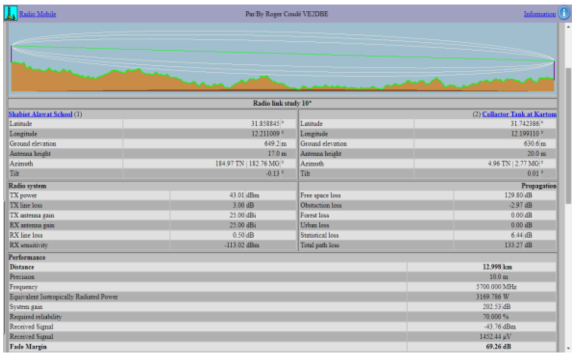


Figure 5. Layout for link 10

Forest and Urban losses in all links are equal to zero due to the fact that the environment is located in a semi-Sahara area.

As expected in equation 1, the free space loss is at its minimum at link 8 than increases slightly with the distance increase between the transmitter and the receiver and reaches its highest value in link 9.

The second successful attempt is the connection among: Idrif work shop station former distribution tank - Aulad Jaber distribution tank - karthoom work shop station. The following figures show the links layout and their simulation results. This is much more enhanced than the first one, because it needs shorter antenna height and the link between main station / collector tank and Aulad Jaber distribution tank will be used for another designed system (IACS2).

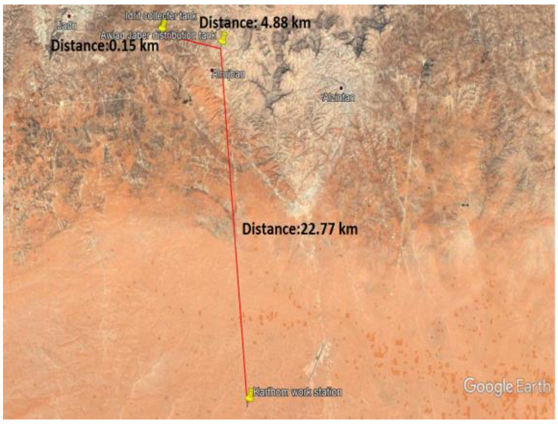


Figure 6. Wireless links layout

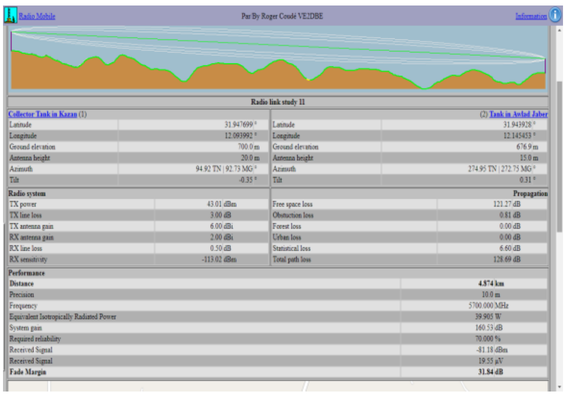


Figure 7. Layout for link 11

The second design feature, as shown in the figures, is to reduce the height of the antenna towers. For example, the height of the antenna required to connect to the old reservoir is only 15 meters as in the figure in the first design. This antenna will also be used to connect the pumping station and the old tank.

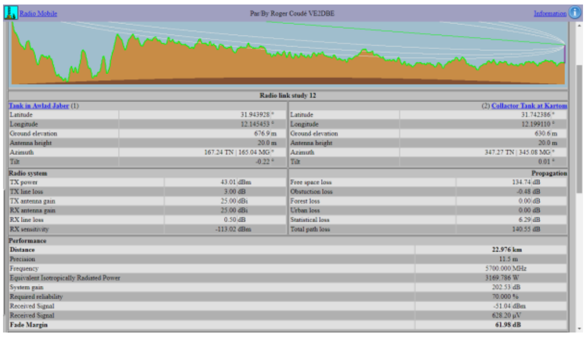


Figure 8. Layout for link 12

VI. CONCLUSION AND FUTURE WORK

Water is one of the most important basic needs for all living beings. Although from sixty decade in previous certain the followed governments have been dug many wells, power, buildings and collector tanks but till now there is a lake in usage water in Rujban city. We tried to overcome this problem and designed an efficient automated water pumping, through tank level and water flow sensing, and controlling system. Our intension of this research work was to establish a flexible, economical and easy configurable system which can solve the main part of our water needing problem. Due to the immensity of the work, we've limited our attention to the design of the wireless network; further work will be entailed in another research.

The system used microcontroller to automate the process of water pumping in an over-head tank storage system and has the ability to detect the level of water in a tank, switch on/off, specific number of pumps regarding to tank level sensing, pump accordingly and display the status on an LCD screen.

The designed IACS1 can manage, control, operate, detect, and display water pumping between two main collector tanks. In addition to designed KACS, IACS2, which is responsible for water pumping from Idrif collector tank to the three far away different places high water distribution tanks.

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BIOGRAPHIES

Omar Ali Zargelin was born in Rujban/Libya, on August 5th,1968. He received BSc degree (vor diploma) in Electrical Engineering in 1998 from the University of Berlin. He got MSc degree in communications as a major then minored in Electronics and computer architecture, in 2003 at the same university. Moreover, he got PhD degree in Electrical and computer Engineering/communication from the university of Denver in Colorado/U.S. in 2014. He is currently a lecturer and head of the department of Electrical Engineering in the university of Aljabal Algharby in Zintan/ Libya.

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