GIS – SCADA Integration for Water Utilities Management, Benefits and Challenges

Salah Muamer Aburawe, ***Almergib University***

***Abstract* — GIS - SCADA integration became of the issue that imposes itself heavily in the field of water supply management worldwide. While the GIS leads the tasks of storage, processing and analysis of spatial data, SCADA system ensures the field monitoring and provides required field data in real-time. But despite the advantages of this integration to reach the desired target only that it faces many challenges both on the side of GIS or SCADA system, like designing of appropriate data model for both systems, as well as the security aspect of the SCADA system. These challenges represent an obstacle in the way of designers to integrate optimally and always need to propose more solutions to reach the desired end of building such an integrated system. This research paper presents a general review of both systems and their potential in water utility management and the possibility of integration with each other to solve problems that are difficult to solve by using one of the two systems individually.**

***Index Terms* — GIS, SCADA, Water Utilities Management.**

I. INTRODUCTION

The technical development became these days as an opening the door for other technologies to take place on the both sides of scientific and practical areas, and whenever increasing the techniques used in any field, the importance of integration with each other will be increased to work as one unit with more efficient, effective and ability to solve the problems facing that field, the integration among the different techniques became one of the most important requirements that must be considered when developing any technology to take advantage of all the features available in the rest of the other technologies. The geospatial information system (GIS) technology became more integrated with many of other techniques; the integration of GIS with the supervision control and data acquisition system (SCADA) has contributed to open new horizons in the management of water utilities despite the presence of some challenges facing this integration.

While GIS implements the functions of storage and preservation of spatial information of the components of the water supply utilities within the geospatial database designed for this purpose, as well as conducting a spatial analysis using many tools available in these systems; SCADA provides the operational data about the status of these facilities in real-time through the continual monitoring using sensors to measure and collect data required for analysis that makes it easier for decision makers to take appropriate decision at the appropriate time during the operation and maintenance, which helps effectively in improving the management level of the water system utilities and gives an opportunity to provide better services.

As is well known to all, the water system includes many of utilities beginning of the source of water and passing through the treatment plants, pumping stations, water tanks and finally to the distribution network which allows the arrival of water to each consumption point in the city, all these utilities pass through a lifetime of several stages, starting from the stage of study and identification of needs followed by design and construction stages then operation and maintenance stages, and by the passage of time and changing of the requirements as a result of changes in population and environment, the system needs to be re-examined again to make some developments and new additions to meet those requirements, so we need to go back to re-apply of the earlier stages again to gain access the best use of this system.

The success of all stages of such engineering projects depends on choosing the best technologies to implement each stage of these stages, where GIS can contribute effectively in all stages through its integration with other systems as Global Positioning System (GPS) and Hydrological and Hydraulic modelling system (H&H); except that the importance of integrating GIS with Supervisory Control And Data Acquisition system (SCADA) for collecting data in real-time stand out clearly in operation and maintenance stage; where this integration is important to prolong the life time such system during this stage as well as getting the benefits to the maximum (Figure 1).

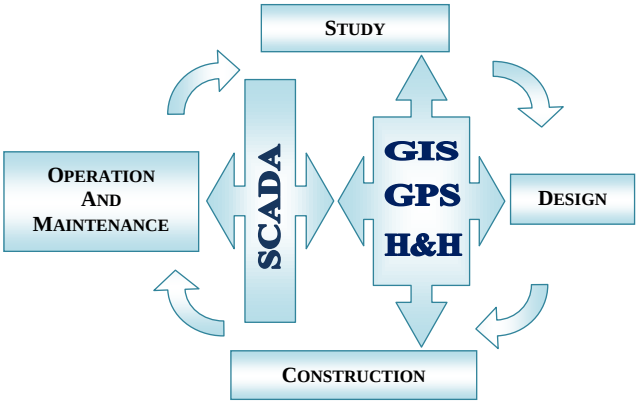

Figure 1: *Stages of Life Cycle of Water Utilities Project*

.

II. GIS TECHNOLOGY

A. Overview

Geospatial information systems (GIS) are those computer systems that help in the use and development of spatial data, there are many reasons which lead to use such systems widely in various fields, for example its high potential for storage, analysis and deliberation of spatial data besides to its ability to integrate with many other systems, which increases the efficiency and breadth of the use, and allows most effective and efficient in the use of available resources and find solutions to intractable problems in the past.

Geospatial information systems consist of hardware and software components. Given the need to manipulate large quantities of spatial data for analysis, the hardware which used by GIS often must have large storage capabilities, as well as high-speed for data manipulation. The GIS software is unique in terms of their ability to deal with coordinates and related information. There are many tools and software packages available to help in the development of GIS.

While the definition of GIS as tool for use with spatial data, we must emphasize the importance of institutional context appropriates for GIS which mostly used as tool to support decision-making, where the effective use of GIS requires more than just purchase of hardware and software, where there are needs to trained personnel to identify measures governing the use of GIS, which must be adhered to apply it properly,

B. GIS in Water Utilities

Started using GIS in water supply is clearly in the beginning of the nineties, which began to be used in the maps preparation and computer modelling, as well as in the water system management within the plans of operation and maintenance.

In the mid-nineties, the using has become more user-application in this area so included verification of the water quality, follow-up the changes in the water system and determine the effectiveness of some treatments that are performed like corrosion control or chlorination, as well as study and assess the feasibility of expanding the system and develop plans for the protection of wells and water sources in general.

With the increasing use of GIS as a tool to ease the tasks of the management since the late the last century eased the burden is clearly on the managers who entrusted them with the responsibility of these tasks because of the ability of GIS to resolve a work which was hard before, where the exchange of data among GIS and other systems like CAD, Supervisory Control And Data Acquisition (SCADA), as well as Hydrological and Hydraulic modeling systems (H&H) are much easier than ever before because of the ability to integrate these systems with one another.

GIS applications in many of water systems affairs like maintenance management, capital planning and customer service became as an urgent issues that imposed by work requirements and the capabilities of these systems to meet these requirements through integration with a lot of other systems-related. Many of us use GIS applications on the internet and on wireless devices widely and intensively, making them an effective tool for managing water systems and other complex infrastructure systems. [1]

Seeking GIS among the most important benefits of using it to increase productivity through increasing efficiency and save time, which clearly contributes to save money and reduce cost. Also GIS contributes to improve the quality of life by making routine tasks easier. In the field of water utilities management GIS can organize information about customers, assets of the water facilities and keep records of maintenance and customer complaints with more efficiently and easily, allowing manipulate this information at the time of need shortly, it also allows the consultants to analyze problems and propose solutions in a timely manner.

Despite the advantages of GIS applications but that the lack of design and effective implementation of these applications as a result of failure to identify the vision and understanding of the requirements can lead to

disappointment because of the large and costly efforts in this context, GIS technology - like other new technologies - is not free of defects and limitations, which represent challenges facing this technology.

Data collection and analysis and prohibitive costs required for that are the first issues that constitute a significant challenge in the face of this technology, besides the high initial costs generally for purchase of hardware and software and conduct ongoing maintenance required. It represents also a learning curve for GIS, privacy issues and the lack of skilled technicians are also some other challenges facing the implementation of GIS applications.

GIS helps decision-makers to find solutions for the problems through the availability of spatial relations linking objects in the site under study, but does not give an absolute solution to the problem.

ArcGIS as one of GIS platforms that can provide these capabilities to water utilities in support of mission-critical business needs. It supports the business models of all water utilities, which include the following: [2]

- Sustainable management of water infrastructure.
- Cost recovery such as water loss control, rate stabilization, and development fees
- Emergency preparedness and response.
- Planning and financing of capital improvements.
- Communication/Transparency with customers.
- Environmental stewardship such as water supply, watershed protection, and conservation.

III. SCADA TECHNOLOGY

A. Overview

Supervisory Control And Data Acquisition (SCADA) is an automation system used widely for remote control and data collection for the status of the field assets of the any system through sensors located in remote locations and to transmit data to a central location either for control or monitoring, and based on data which are collected, supervisory commands be issued to the controllers in the field, which are usually called (field devices).

SCADA system generally includes the following components (Figure 2):

- Sensors for measuring data, which can be called (field devices).
- Local processors that collect data and communicate with the site's instruments and operating equipment called Programmable Logic Controller (PLC), Remote Terminal Unit (RTU).
- Short range communications among local processors, instruments, and operating equipment
- Host computer as central point of human monitoring and control of the processes, storing databases, and display of statistical control charts, and reports.
- Long range communications among local processors and host computers using wired or wireless network connections.

SCADA systems differ from DCSs (Distributed Control Systems) which are generally found in plant sites. While DCSs cover the plant site, SCADA systems cover much larger geographic areas. Also, due to the remoteness many of these often require the use of wireless communications.

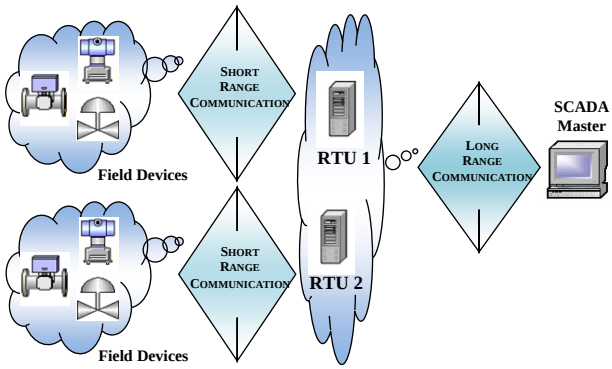

Figure 2: *Simple SCADA Architecture*

B. SCADA in Water Utilities

SCADA used in water system in the control of the distribution network and other utilities in the system from a central location by data acquisition about the status of all components of the system in real-time, data can be transferred from field devices to the central location, as well as in the opposite direction, and presentation of these data and the results analyzed on computer screens in a central location.

SCADA system can also use to control the supply of raw water and to give information about water levels in reservoirs, can also be used to predict the water demand as well as give information about the dates of preventive maintenance for water utilities based on operating times.

SCADA system used to deal with the field assets of the water supply system, including water sources, pumping stations, treatment plants, reservoirs, and water distribution network to do the following: [3, 4]

- Monitoring and control of operational processes to ensure access to required performance continuously.
- Run the system from one central location and reduce the levels of dependence on the manpower needed for operations through automation.
- Provide data about the system behavior and performance through effective procedures for asset management.
- Provide a system to monitor the development of operational objectives which can be gained access.
- Provide a warning system that would allow diagnosis of faults remotely from a central location, and thus send a team of specialist to conduct maintenance operations in a timely manner. [5]

IV. GIS - SCADA INTEGRATION

With a convergence of GIS and SCADA system, many different methodologies have been proposed for integration among these systems which contributed to open new horizons in the management of water utilities, each of these methodologies aim to provide a comprehensive tactics to achieve one operational network benefit from the advantages of both systems, While some experts propose GIS to serve as a base system for this integration would prefer others to take SCADA as a base system. However, for each of these methodologies there are benefits and limitations.

While designed SCADA with limited database size with high-speed data processing and high reliability and an ability of a simple graphical display for data and results, GIS on the other hand is characterized by the ability to deal with high volume of spatial and non-spatial data, besides high capacity to analyze the data and display results in more clarity and accuracy, but at the same time GIS not designed originally to deal with operational tools in real time as is the case for the SCADA system which is limitation for the first and benefit for the second, making a lot of effort to integrate SCADA with GIS in one platform, which can support the manipulation of spatial and non-spatial data and analysis in real time.

A. GIS as base system for integration

Given the need for integration among GIS and some other systems to take advantage of the potential is important to verify the ability of GIS to be the basis for this integrated system with other systems.

Because of the high ability of GIS on the representation and spatial analysis through many tools, GIS has the ability to view and analyze all data on the distribution network and its asset management, and GIS techniques are not effective and useful in increasing the operational efficiency of the network only, but also in improve of design policies, decision making, communication and information exchange.

In addition, the GIS can help in the daily maintenance operations for the distribution network, also provides high accuracy of spatial and non-spatial information to maintenance teams to perform their tasks with ease.

To increase the effectiveness of performance, the GIS integrated with other systems, provides greater ease, less cost and support the implementation of additional functions with other specialized nature, GIS is working as the basis for this integrated system and meets all the requirements through the geospatial database that allows integration and permanent update all system resources, thus contributing to the speed performance necessary to modernize and increase the compatibility of data with other systems, and that every system in the tool integration with a mission dedicated to do, GIS is not a substitute for any of these systems, but the resulting tool is a complete system wide effectiveness and any system in this tool can enhances its capabilities and thus contribute to improving the results.

B. Advantages of integration

GIS and SCADA integration Contributes in general to provide an integrated system characterized by all advantages of both systems and trying to address the shortcomings of both systems through the capabilities of the other system, this integration provides many benefits for water supply utilities, and show such benefits in increased efficiency of the operation processes, while the SCADA system provides the field data reports about all water utilities in the of the system in real time, GIS using its abilities to analyze spatial and non-spatial data performs many of the tasks that contribute significantly to increase the operational efficiency of the system.

This integrated system between GIS and SCADA can provide the ability to display spatial data on maps of water utilities, distribution network besides the operational information in real-time which provide the data necessary for hydraulic modelling software to perform the hydraulic analysis necessary to determine the status of all components of the operating system for the distribution network which allows to take the appropriate decision about any emergency that may arise during the operational process of the network.

It is also possible using this integrated system as a control system of comprehensive and periodic maintenance, and contribute to reduce the cost to a large extent, as well as to improve the level of communication among the departments of the system, and data exchange and to maintain the accuracy and integrity of information at the same time, this improvement in access to data in the database will help decision makers and users to gain access information quickly and accurately in real time.

C. Challenges and Recommendations

Although all the above-mentioned advantages of this integration between GIS and SCADA system there are some issues that must be taken in the consideration during the implementation of this integration between these two systems. Although addressing some of non-compatibility points between these two systems the process is not always going smoothly, there are issues that need to be addressed. First, must pay attention to the issue of data modelling in each of SCADA and GIS which is different from one organization to another, both systems retain its different understanding for the identity of the same objects in water supply system, as well as to unify of the strategy mapping including maintenance data and expansion and upgrading of equipment, as that any changes in one system of these two systems require synchronization with the amendments in the other system.

The systems integration is a way to combine the advantages of integrated systems to reduce the size of the shortcomings and limitations, however remain some deficiencies as burdens on this integrated system, and the problem will be increase as a result of the increase the burden career assigned to this integrated system, the most important deficiencies that get much interest by the researchers what could be called the security issues, and despite all these challenges remain opportunities for integration between SCADA and GIS systems are important and deserve all this attention. Because of some legal and technical issues, the issue of integration with the SCADA system may faces some of the complications due the challenges facing SCADA regarding the issue of information security, which depend heavily on the communication network used in the system, which makes a lot of users of this integration to seek to develop a process to replicate all the data to an internal database for use in the integration processes, which ensures that this integration will not affect to SCADA operations, but on the other hand it will cause delay time between the stage of getting data in real time using SCADA and display data in GIS.

To ensure the success of the integration between GIS and SCADA system in the management of water supply system must be given enough importance for the needs study, where that most of the deficiencies and challenges of this integration stand out as a result of the lack of good understanding of the requirements resulting in the design of the integrated system are not appropriate to the needs and thus the failure to achieve the desired goals.

Of the other important issues that are recommended to take in consideration is the adequate focus to understand the components of water supply system under study from the viewpoint of SCADA and also GIS, and access to design data model to accommodate all the data on the system so that it is appropriate for both the integrated systems.

It is also recommended to conduct a comprehensive study of the appropriate communication network, which will be used for communication among the various SCADA devices, both central and field to reduce the challenges posed by security issues of SCADA system.

Besides the permanent attention to the issue of training that allows for the provision of technicians who are able to run the integrated system and make the developments in the future to accommodate all the expansions of the system.

V. CONCLUSIONS

The issue of GIS - SCADA integration in the water supply system management of the complex issues that need to discuss many of the details for its coverage. This paper presents in brief some of the features that are characterized by both of these two systems generally, besides their limitations, as well as has been brief idea of the components of the SCADA system and what it can provides of features to qualify to be an ideal partner with GIS in building an integrated system to solve some problems facing the water supply systems.

Emerged many of the researches in this area suggest many methodologies for this integration, where tried a lot of water managements to bring the SCADA in GIS, while other managements prefers to bring GIS in SCADA system, in both cases, the GIS cannot replace SCADA, but the need requires that both of the two systems must plays together in an integrated manner and would contribute to solve the problems which cannot solve by each of the two systems individually, this integration can be by providing SCADA field data in real time through a network of sensors distributed in the field at remote locations, and GIS can save the locations of these devices in the spatial database containing all data about the water system, and through the appropriate analysis which can be done by GIS tools can be inferred information contribute significantly in helping decision makers to take appropriate decision in respect of any emergency may occur in the system.

By using this integrated system in the water supply system management can be obtained on an interactive map for the system of water supply and distribution network to simulate reality through the field data in real time which can provided by SCADA system, besides the results of analysis of these data that help to take the right decision and send the instructions thereon directly to the field devices to deal with any emergency problem.

REFERENCES

[1] U.M. Shamsi, “GIS Applications for Water, Wastewater and Stormwater Systems”, Taylor & Francis Group, 2005.

[2] “Implementing ArcGIS for Water Utilities”An ESRI white paper, December 2016

[3] Thomas M. Walski, Donald V. Chase, Dragan A. Savic, Walter Grayman, Stephen Beckwith and Edmundo Koelle, “Advanced Water Distribution Modeling and Management”, CH 15 SCADA Basics, Bentley Institute Press, January 2003.

[4] Pranam Joshi, Tom Walski, Sudhir Gandhi, Jeffrey A. Andrews, Carl F. Newswanger, “Case Study: Linking Bristol Babcock’s SCADA System to WaterCAD, a Water Distribution Modeling Tool”, American Water Works Association DSS Conference, 2004.

[5] Salah Muamer Aburawe, Ahmad Rodzi Mahmud, “Water Loss Control and Real-time Leakage Detection using GIS Technology”, Geomatics Technologies in the City, First International Geomatics Symposium in Saudi Arabia, Jeddah, May 2011.

BIOGRAPHIES

Salah Muamer Aburawe was born in Tripoli /Libya, on August 14, 1969. He received Bsc degree in Civil Engineering from Tripoli University, in 1993. He got Msc degree in Remote sensing and GIS from University Putra Malaysia / Malaysia in 2010. Moreover, he got PhD degree in GIS and Geomatic Engineering from University Putra Malaysia / Malaysia in 2014, where he is currently lecturer in Department of Civil Engineering at AlMergib University / Libya. His research field is GIS Applications.