# Smart Irrigation for Green Areas in Urban Zones Case Study: Madinaty Smart Irrigation System



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# Case Study: Madinaty Smart Irrigation System

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**Abstract:** To improve the control of the irrigation process, this study introduces the Smart Irrigation System (SIS). The system involves the use of the Internet of Things (IoT) to save irrigation water by automatically watering the green areas based on their accurate water requirements, and to avoid the disadvantages of the old traditional irrigation methods. Madinaty is a compound in northeast Cairo governorate, Egypt. Madinaty SIS uses microcontrollers for the estimation of the plant water requirements based on the data of soil temperature and moisture levels transmitted by the sensors installed in the field. The SCADA master station, with its hardware and the third-party software, provides the irrigation team with the capability to monitor and assists them in decision-making regarding the irrigation process. Field data collected showed that the SIS in Madinaty saves about 50% of the irrigation water consumption.

**Keywords:** Microcontroller; Moisture Sensor; Relay; Resistance Temperature Detector (RTD); Smart Irrigation System; Soil Moisture.

**Abbreviations:**

| | |
|---|---|
| EGP | Egyptian Pound |
| ET | Evapotranspiration |
| $ET_o$ | Reference Evapotranspiration |
| IoT | Internet of Things |
| SCADA | Supervisory Control And Data Acquisition |
| SIS | Smart Irrigation System |
| TMS | Traditional Manual System |
| WWTP | Waste Water Treatment Plant |

## 1. Introduction and Literature Review

Water is required for all plants, whether they are on a lush golf course, a wiry vineyard, or waving wheat fields. As a result of the global climate change and population growth, water became scarce and frequently expensive, resource. Therefore, smart irrigation system (SIS) that uses less water is gaining popularity. **Aires 2019** [1] reported that SIS industry reached more than 1.5 billion $ in 2022, growing at a 17.2 % annual growth rate between 2016 and 2022. SIS uses field soil moisture and weather sensors to water crops with the exact water requirement to increase the effeciency of water use. Data is transmitted to the main station where it is analysed and decisions are made and fed to the controllers to lead the advanced technology exists regarding the time and quantity of water to be applied to the field. SIS technologies give the ability growers to monitor soil moisture levels and weather conditions using sensors and controllers, allowing them to use water more efficiently and effectively.

Lately, research work regarding the SIS topic is intensively carried out. Examples of published research papers are introduced and discussed herein.

**Aishwarya 2017** [2] introduced the using of IoT technique at fulfilling water requirements of the crops, by monitoring the soil moisture and other environmental parameters. The logs the sensor data to the cloud and the farmer can monitor and control all the water pumps remotely over internet using Android application. It consists of wireless sensor node with Arduino publishing sensor data to cloud using Wi-Fi module and controlling the pump using relay.

**Wafa et al. 2018** [3] presented recent design technology of irrigation management system using wireless sensor networks. They developed sensor network technology to allow for the integration of new hardware and software in the irrigation sector. Their SIS used temperature, water level and humidity sensors to establish watering requirements. They said that their system was easy to install and need less labor and time to operate.

**Chuah et al. 2018** [4] employed cyber-physical system (CPS) in vertical farming to carry out remote monitoring of the plants growth. Results showed that the newly developed CPS system was able to reduce manpower, and to monitor and control the plants growths factors such as light, humidity, temperature, pH level and volume of $CO_2$. In addition, their CPS system could be used to eliminate the growth of algae.

**Arul et al. 2019** [5] proposed a hybrid method to select the irrigation method automatically based on soil moisture level and the climate data. They reported that using the rapid growing technologies and IoT enabled smart irrigation controllers to help improving the agriculture sector.

**García et al. 2020** [6] provided an overview of the state of the art regarding IoT irrigation systems for agriculture. She identified the most monitored parameters to characterize water quality for irrigation, soil and weather conditions. She stressed the most utilized nodes to implement IoT (Internet of Things) and WSN (Wireless Sensor Network) for irrigation. She finally introduced a 4-layer architecture proposal for the management of crop irrigation.

**Jadhav et al. 2022** [7] presented IoT based Irrigation system that could automatically water plants depending on field sensors. They showed the role of automatic irrigation scheduling in improving water use efficiency compared to manual irrigation. They cleared that the system had low maintenance cost. easy to use, and the parameters can be easily realized by using IoT.

## 2. Compositions and Functions of The System

The smart irrigation system (SIS) is composed of four modules and four layers (see figure (1)). These layers and modules are presented hereafter.

### *2.1. The Four modules of SIS*

The four modules of the SIS are the field monitoring module, the water supply monitoring module, the total control module, and the crop water requirement data module. Details of these modules are given as follows:

- The field monitoring module monitors and collects soil data, hydrological data, and meteorological data that affect crop growth and then transmits this data to the target database.
- The water supply monitoring module collects and monitor the amount of water flowing through the water supply pipe.
- The total control module automatically controls the opening and closing of valves, displays the operating condition of each water pump at the water head site, controls pump start-stop and response system based on the quantity of water calculated by the crop water requirement.
- The crop water requirement data module utilises real-time monitoring data to provide real-time corrections to the original crop growth model. It is gradually developed based on data collected and calculating the annual water requirements of crops during various growth stages.

### *2.2. The Four layers of SIS*

The four layers of the SIS are the data acquisition layer, the Intelligent transport layer, the big data centre layer, and the decision management layer. Details of these modules are given in Figure (2):

- The data acquisition layer collects, monitors, and analyses field soil moisture and weather data, among other things.
- The Intelligent transport layer utilises the internet of things and other novel technologies and methods. Then, it transmits the collected data to the target database automatically.

- The big data centre layer stores, calibrates, mines, and extracts historical data resources to determine the relationship between crop water requirements during various growing seasons, soil moisture, weather, and precipitation.
- The decision management layer in accordance with the extraction relationship, controls the amount of irrigation, the duration of irrigation, and the opening and closing of pipe valves.

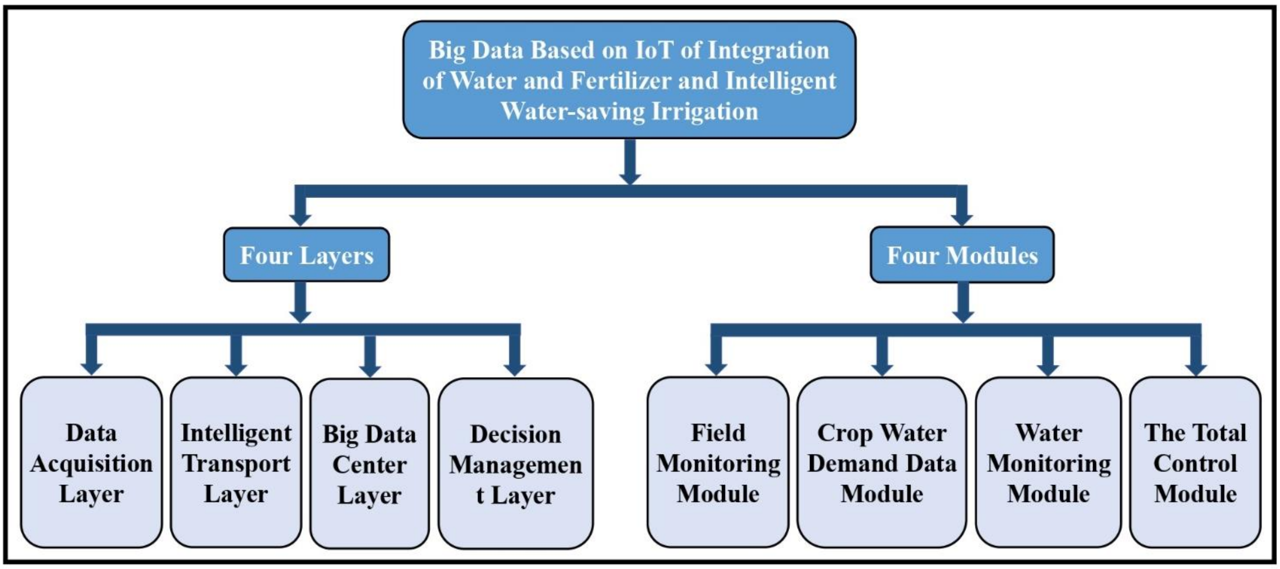


Figure (1): System Structure Diagram

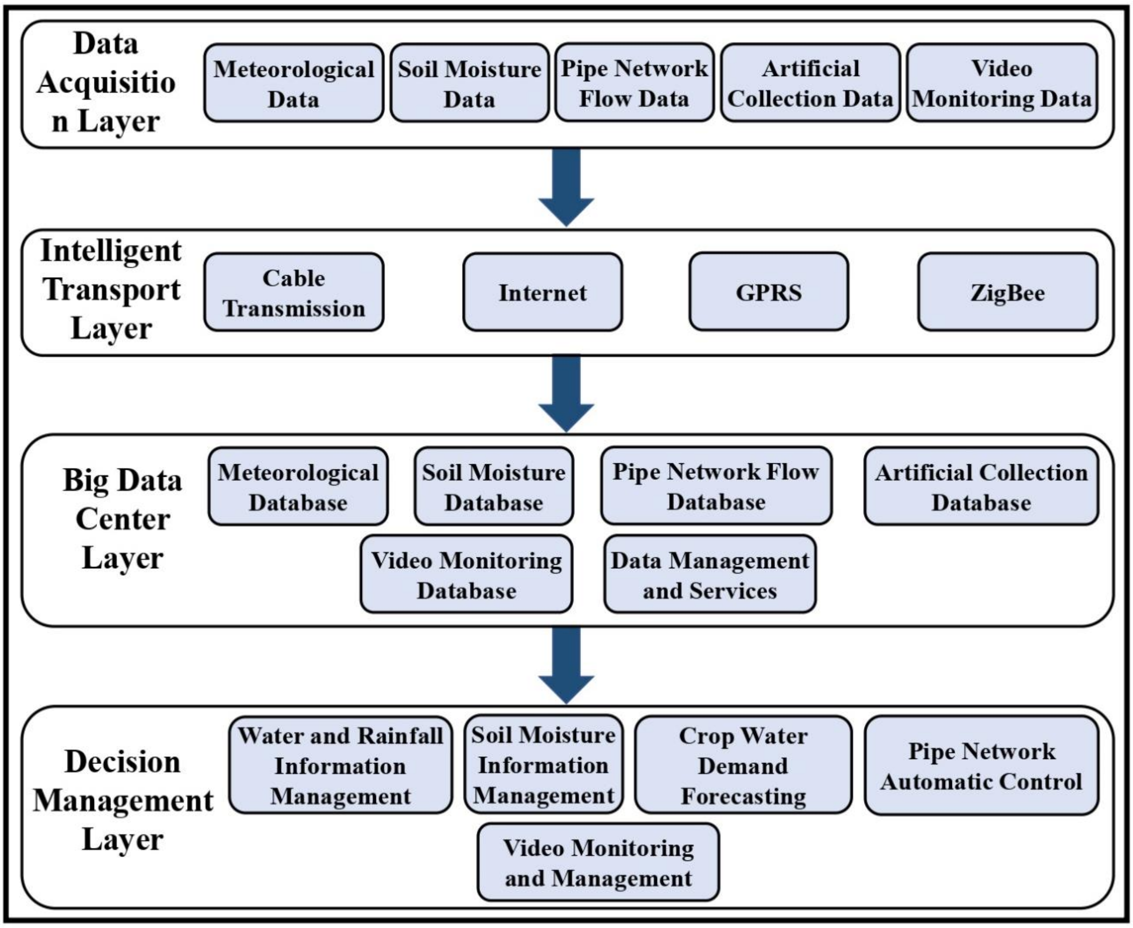


Figure (2): System Design Diagram

## 3. Case Study: Madinaty Compound in Cairo

***Madinaty*** is a residence compound located in northeast Cairo governorate, Egypt. The compound construction has begun on July 2006, the city is being built over an area of 3,200 Hectares (32,000,000 m$^2$) with a total budget of 60 billion EGP. Advanced infrastructure for water and electricity distribution is used in this project.

The temperature in Madinaty is mostly high and the average precipitation is low. The compound climate is classified as a hot dry dessert climate as most parts in Egypt. Table (1) gives recorded temperatures and average precepitation in the compund.

Table (1): Temperatures and average precepitation in Madinaty.

| Climate data for Madinaty | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
| Average high °C (°F) | 18 (64) | 19.7 (68) | 23.2 (74) | 27.9 (82) | 32.2 (90) | 34.4 (94) | 34.9 (95) | 34.5 (94) | 31.9 (89) | 29.7 (86) | 24.8 (77) | 20 (68) | 27.6 (82) |
| Daily mean °C (°F) | 13 (55) | 13.8 (57) | 16.6 (62) | 20.4 (69) | 24.2 (76) | 26.8 (80) | 27.8 (82) | 27.7 (82) | 25.5 (78) | 23.4 (74) | 19.2 (67) | 14.6 (58) | 21.1 (70) |
| Average low °C (°F) | 7.8 (46) | 8 (46) | 10.1 (50) | 12.9 (55) | 16.3 (61) | 19.3 (67) | 20.7 (69) | 21 (70) | 19.1 (66) | 17.1 (63) | 13.7 (57) | 9.3 (49) | 14.6 (58) |
| Average precipitation mm (inches) | 6 (0.2) | 4 (0.2) | 4 (0.2) | 2 (0.1) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 1 (0) | 4 (0.2) | 5 (0.2) | 26 (1.1) |
| Source: Climate-Data.org (altitude: 230m) | | | | | | | | | | | | | |

## 4. Madinaty Smart Irrigation System

Madinaty compound has a total area of over 5.7 million square metres of green area. The watering requirements of plants vary according to a variety of parameters. These parameters include weather conditions such as sun exposure, humidity level, and wind speed, soil type, and plant species. Field controllers calculate a watering demand using complex algorithms.

The SCADA (Supervisory Control And Data Acquisition) system monitors and provides the appropriate triggers as needed to streamline the irrigation process. The main part of the SCADA system is the system master station. Its primary function is to provide the operation team with the capability to monitor and assist in decision-making regarding the green landscape irrigation process of the Madinaty compound.

The integrated process is conducted through several levels:

- SCADA master station software,
- SCADA master station hardware and third-party software,
- Communication infrastructure,
- Field servers,
- Field controllers, and
- Controlled field equipment including flow sensors and valves.

Figure (3) shows a summary of the major system components and the related interfaces and protocols of Madinaty compound smart irrigation system. Following is more details about the system:

- The Master Station communicates with several field irrigation controllers in order to exchange necessary process data and control capabilities. The controllers are interfaced via intermediate gateways dubbed "Field Servers", which act as protocol converters.
- The Modbus/TCP protocol is used to communicate between SCADA systems and these gateways.

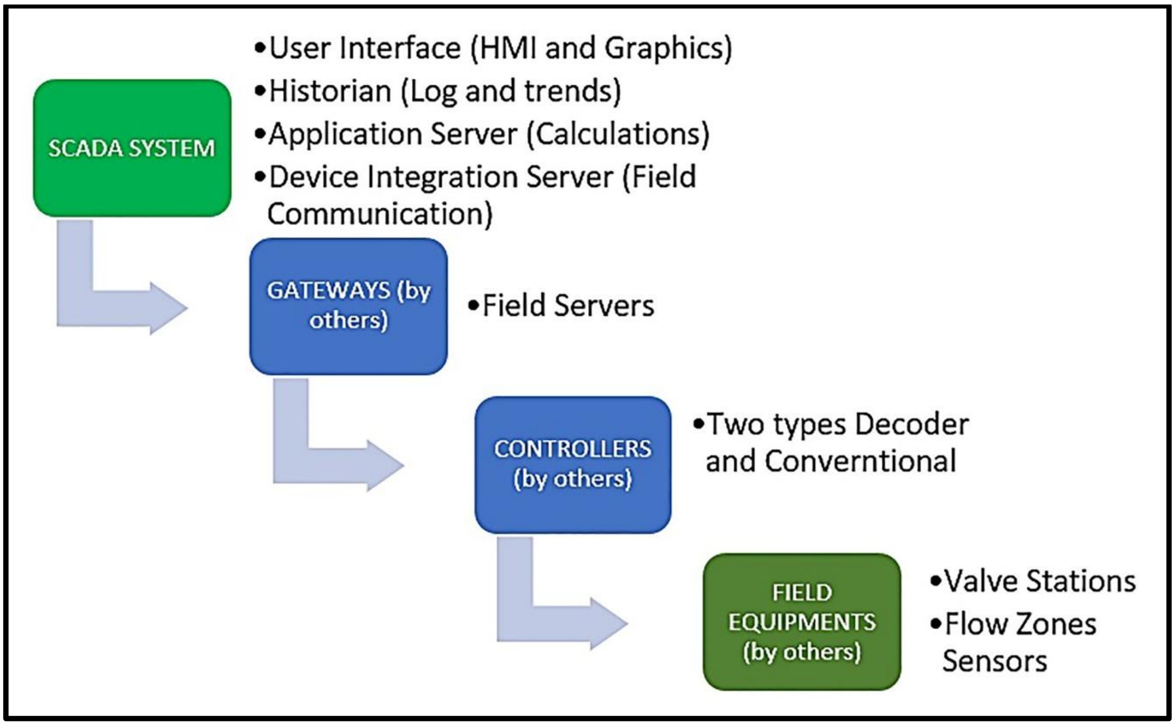


Figure (3): Levels of the SIS integrated process in Madinaty

- The Controller database is logically divided into groups:
  - Main Functions of the Controller,
  - Program, Diagnostics,
  - Flow Zones, and
  - Stations.
- Each of these groups has its own set of characteristics and control requirements.
- Each Controller, Flow Sensor, and Station has its own Faceplate (s) on the SCADA graphics, which displays the equipment's status and allows the operator to control it via the Faceplate (s).

- In addition to this, there are additional support systems that provide inputs to the process including:
  - Madinaty Wastewater Treatment Plant (WWTP)
  - Weather Stations (Three Weather Stations provide weather inputs).
- As mentioned earlier, the weather of the compound is hot dessert climate with low rain amount. This leads that the plants and the landscapes need high amount of water for irrigation.
- Using the old traditional irrigation systems, records showed that the amount of water was not accurate, and the performance of the irrigation is affected.
- It was suggested to apply the SIS aiming at saving a notable amount of water, energy, and the labour cost, and reducing the maintenance and operation cost.

- The Smart Irrigation System of Madinaty project, has launched in 2019. As per the system acritude and design, it was planned to use 150 controllers alongside with several number of field valves and sensors.
- Three weather stations will be installed and allocated in three different locations in the compound to get the accurate climate data such as air temperature, humidity, wind speed, wind direction, solar radiation and the day accumulated reference evapotranspiration.
- Knowing all these data, the SCADA system function is to calculate the actual needed water for planting and irrigation.
- In Figure (4), the Madinaty Irrigation System faceplate shows the different compound zones and the irrigation status. It also shows the data received from the weather station and all the data required by the operator that helps him to take the right decision in the right time.

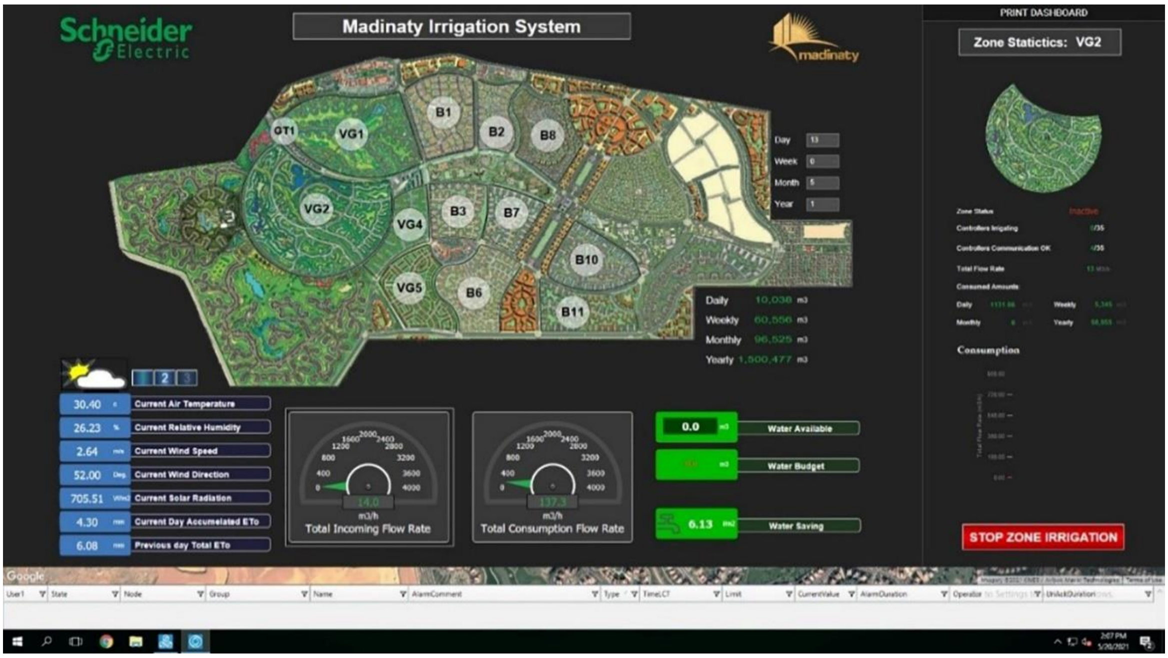


Figure (4): Madinaty Irrigation System faceplate

- The SCADA systems consists of several layers to show all the field status for the irrigation controllers and for the zones themselves, also going deeper to the valves of layer itself as shown in Figures (5, 6 and 7).

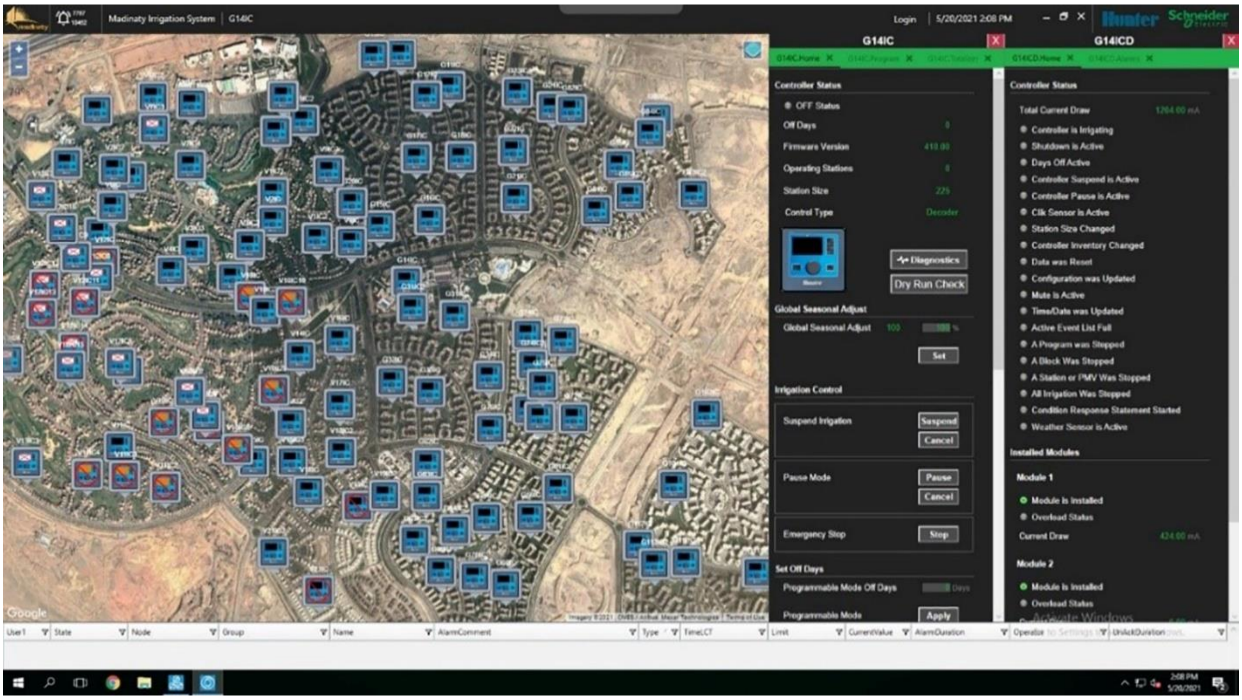

Figure (5): Layer of Irrigation controllers

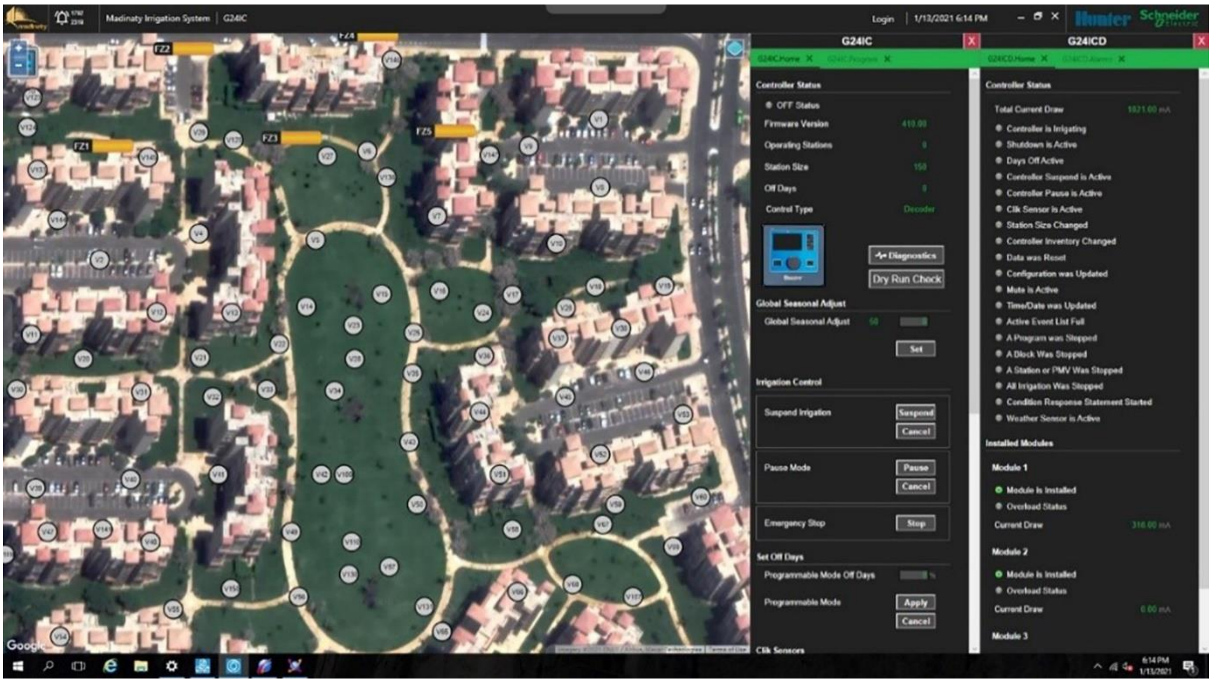

Figure (6):  Layer of Irrigation valves

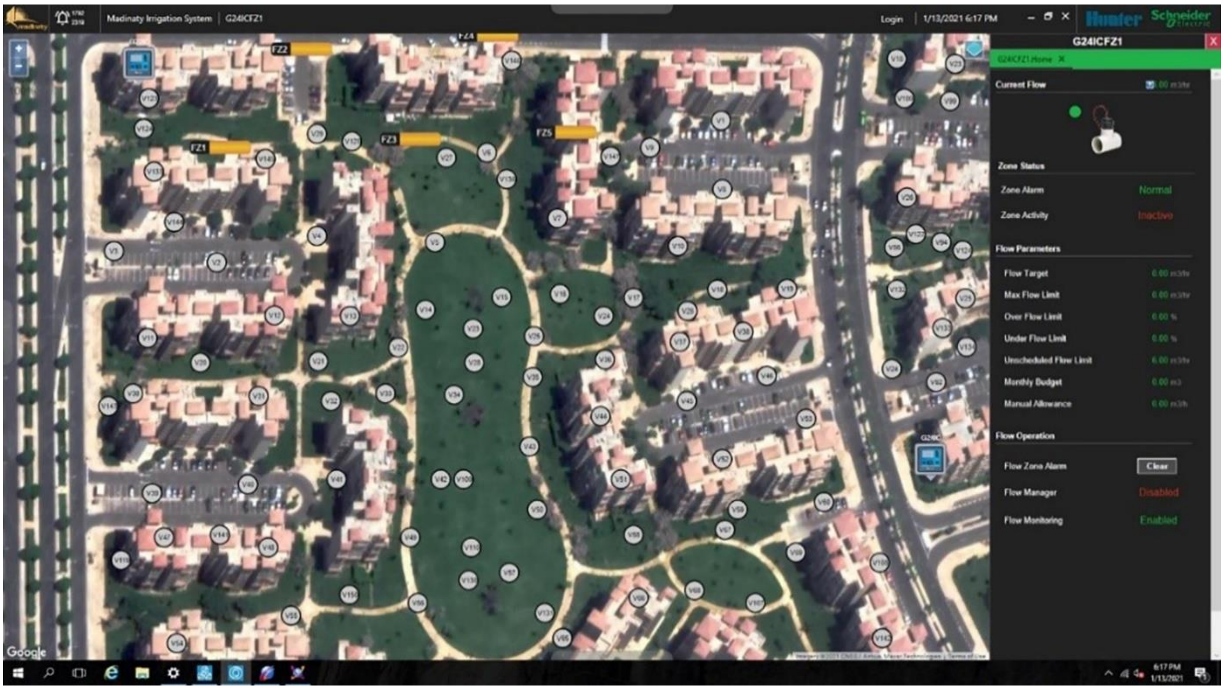

Figure (7): Layer of Irrigation flow

## 5. Evaluation of Madinaty Smart Irrigation System

The SIS is now installed in around 55% of the compound and has already shown positive impact in the water and energy saving.

The water saving from the system is calculated by using the below equation:

**Water saving = This year month total flow – Similar month total flow of 2020.**

And the following conditions and observations are conducted:

- The historical data of the water demand in the compound was saved during several past years.
- In these years, the irrigation system was a traditional manual system (TMS).
- To calculate the water saving and the cost saving, water use data given in Table (2) was used as reference.
- Table (2) shows the water use in 2020 for every day in every month.
- The average water use is given in the last row.
- As expected, the average consumption increases in the summer season due to high temperature leading to an increase the evapotranspiration (ET).
- Table (3) gives the water use data in 2021 in July.
- The Comparison between data of Table (3) (using SIS) with column of July in Table (2) (using TMS) is given in Table (4).
- The percent reduction of average water uses in July when applying SIS is more than 48%.
- The same comparison is shown in Figure (8):
    - The black line gives data of irrigation water use in July 2020 where TMS was used.
    - The blue line gives data of irrigation water use in July 2021 where SIS was used.

- The difference is clear and tells water saving when using SIS.
- The data in day 7 in July 2020 is unexpectedly small and may be due to personal or instrumental error.

Table (2): Irrigation water use in 2020 (L/m$^2$/day).

| 2020 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4.8 | 3.7 | 5 | 6.8 | 9 | 12.9 | 14.1 | 11.8 | 13.6 | 11.8 | 8.1 | 4.4 |
| 2 | 4.8 | 5.3 | 5.4 | 6.1 | 8.4 | 12.7 | 13 | 12.8 | 13.1 | 11.2 | 8.1 | 4.6 |
| 3 | 4.2 | 5.3 | 4.9 | 6.9 | 9 | 12.4 | 12.7 | 13.2 | 10.6 | 11.1 | 7.4 | 5.1 |
| 4 | 4.8 | 4.7 | 5.2 | 7.4 | 9 | 12.6 | 13.5 | 13.4 | 12.9 | 10.8 | 8 | 4.9 |
| 5 | 5.2 | 4.6 | 4.8 | 7.2 | 8.7 | 12.4 | 13.3 | 13.2 | 11.9 | 7.7 | 7.9 | 4.9 |
| 6 | 4.3 | 5.3 | 4.7 | 7.9 | 7.8 | 12.5 | 12.3 | 13.9 | 11.4 | 10.7 | 8.1 | 5.1 |
| 7 | 4.8 | 4.2 | 4.9 | 7.5 | 9.2 | 11.1 | 7.2 | 12.7 | 12.6 | 10.9 | 6.1 | 4.7 |
| 8 | 4.9 | 4.4 | 5.2 | 8.1 | 9.2 | 13.1 | 14 | 13.3 | 13.3 | 5.4 | 7.1 | 5.4 |
| 9 | 5.1 | 4.6 | 5.4 | 7 | 8.4 | 12.4 | 13.6 | 12.6 | 11.8 | 7 | 6.9 | 5.2 |
| 10 | 4.3 | 4.8 | 5.3 | 7.4 | 9.5 | 12.9 | 14 | 13.6 | 11 | 10.3 | 6.4 | 4.7 |
| 11 | 4.7 | 4.7 | 4.9 | 6.8 | 9.8 | 13.2 | 13 | 13.5 | 11.6 | 11.3 | 6.6 | 4.2 |
| 12 | 5.2 | 5 | 5 | 7.9 | 9.3 | 13.4 | 12.9 | 13.3 | 12.2 | 11.2 | 6.9 | 5.8 |
| 13 | 5.5 | 5.1 | 10.2 | 7.7 | 9.7 | 13.4 | 12.5 | 13.7 | 12.1 | 11.2 | 7 | 5 |
| 14 | 4.7 | 4.8 | 4.6 | 8 | 9.4 | 11.3 | 13.5 | 13.9 | 12.1 | 10.8 | 6.9 | 4.8 |
| 15 | 4.8 | 5 | 3.8 | 7.3 | 9.3 | 13.3 | 13.2 | 13.8 | 12.8 | 9.5 | 6 | 4.9 |
| 16 | 5.3 | 5.3 | 3.6 | 7.9 | 8.7 | 13.5 | 13.1 | 13.7 | 12.3 | 9.1 | 6.1 | 4.3 |
| 17 | 3.3 | 5.5 | 4.5 | 7.9 | 9.8 | 14 | 13.1 | 13.5 | 11 | 9.4 | 6.1 | 4.5 |
| 18 | 5.3 | 5.7 | 40 | 7.9 | 10 | 13.7 | 13.9 | 13.4 | 12.6 | 7 | 5.8 | 4 |
| 19 | 5.1 | 3.3 | 4.9 | 8.4 | 10.3 | 13.4 | 13.7 | 13.5 | 12.4 | 8.2 | 5.4 | 3.9 |
| 20 | 4.2 | 4.6 | 3.8 | 8.2 | 10.8 | 12 | 13.7 | 13.3 | 12.8 | 9.4 | 5.2 | 4.6 |
| 21 | 5.1 | 4.9 | 4.1 | 8.1 | 8.4 | 12.9 | 13.2 | 13.1 | 12.3 | 9.1 | 3.6 | 4.4 |
| 22 | 4.7 | 5 | 4.5 | 8.4 | 13.1 | 12.4 | 13.4 | 14.3 | 12.5 | 8.2 | 5.9 | 4.5 |
| 23 | 4.7 | 5.1 | 4.8 | 8 | 11.9 | 12.4 | 13.1 | 13.3 | 8.8 | 8.9 | 5.5 | 4.5 |
| 24 | 4 | 0.6 | 5.5 | 8 | 11.2 | 11.1 | 13.1 | 13.7 | 11.6 | 8.7 | 5.5 | 4.6 |
| 25 | 4.8 | 4.4 | 5.2 | 7.9 | 11.9 | 12.9 | 14 | 13.5 | 10.4 | 8.9 | 5 | 5 |
| 26 | 5 | 4.7 | 5 | 8.7 | 13 | 14.1 | 13.9 | 13.8 | 10.1 | 8.4 | 4.4 | 4.2 |
| 27 | 5.7 | 4.6 | 4.9 | 8.1 | 13.3 | 12.7 | 13.5 | 13.9 | 11.7 | 8.4 | 4.8 | 4.4 |
| 28 | 5 | 4.3 | 4.8 | 8.5 | 12.8 | 11.5 | 13.3 | 13.1 | 11 | 8.5 | 4.7 | 3.9 |
| 29 | 5 | 4.8 | 5.2 | 8.2 | 12.8 | 12.5 | 13.2 | 12.9 | 12.4 | 8.1 | 4.4 | 4.8 |
| 30 | 4.5 | 0 | 6.6 | 8.5 | 12.2 | 13 | 12.8 | 13.5 | 11.7 | 7.5 | 4.3 | 4.4 |
| 31 | 4.9 | 0 | 6.3 | 0 | 13.2 | 0 | 11.8 | 10 | 0 | 7.8 | 0 | 3.3 |
| AVG | 4.8 | 4.6 | 5.1 | 7.7 | 10.3 | 12.7 | 13.1 | 13.3 | 11.9 | 9.2 | 6.1 | 4.6 |

Table (3): Irrigation water use in July - 2021 (L/m$^2$/day).

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| day | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| consumption | 6.4 | 7 | 7.1 | 6.8 | 6.9 | 7.2 | 6.8 | 7.1 | 7.5 | 6.4 | 65 |
| day | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| consumption | 6.9 | 7.3 | 6.4 | 6.3 | 7 | 7.1 | 7.2 | 7.3 | 6.8 | 6.9 | 7.2 |
| day | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | | |
| consumption | 6.4 | 7 | 6.2 | 6.1 | 6.5 | 7 | 7.2 | 7.1 | 6.7 | | |

Table (4): Comparison between SIS and TMS

| water use in July (L/m$^2$/day) | SIS | TMS | Difference | Percent Reduction |
|---|---|---|---|---|
| Average | 6.8 | 13.1 | 6.3 | 48.0% |
| Maximum | 7.5 | 14.1 | 6.6 | 46.8% |
| Minimum | 6.1 | 7.2 | 1.1 | 15.2% |

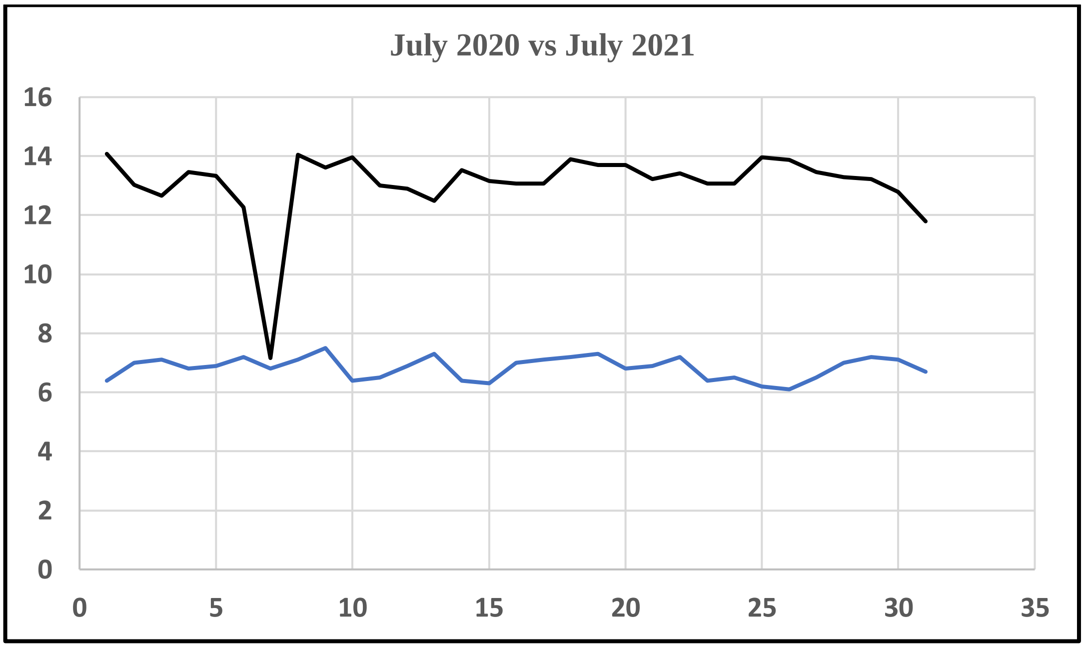


Figure (8): Water use in in July 2020 vs July 2021

## 6. Conclusion

In this paper, the following was studied and concluded:

- The paper presented smart irrigation system (SIS) and its components.
- The superiority of SIS over traditional manual system (TMS) was discussed.
- The case study of applying SIS in Madinaty compound was studied.
- Data for water use in irrigating the green areas in case of using TMS and after applying SIS was collected.

- The comparison between the two cases showed percent decrease in water use in green area irrigation when applying SIS by 48.0%, 46.8% and 15.2% in values of average, maximum, and minimum, respectively.
- The study stressed the need for implementing this kind of SIS in the new cities in Egypt.

## References

[1] Aires, (2019). *www.aires.com*. Retrieved from www.aires.com.

[2] Aishwarya Kagalkar (2017). ‘‘Smart Irrigation System″. International Journal of Engineering, Research & Technology (IJERT)_ Vol. 6 Issue 05, May – 2017

[3] Wafa Difallah et al. (2018). ‘‘Smart Irrigation System″. Conference Paper, June 2018, the 1st Workshop on Electrical Engineering & Computer Science

[4] Y. D. Chuah et al. (2018).‘‘Implementation of smart monitoring system in vertical farming”, International Conference on Sustainable Energy and Green Technology 2018.

[5] Arul Anitha et al. (2019). ‘‘A Hybrid Method for Smart Irrigation System″. International Journal of Recent Technology and Engineering (IJRTE). Vol. 8 Issue 3, September 2019.

[6] García L et al. (2020). ‘‘IoT-Based Smart Irrigation Systems: An Overview on the Recent Trends on Sensors and IoT Systems for Irrigation in Precision Agriculture″, Sensors 2020, 20, 1042 _ www.mdpi.com/journal/sensors

[7] Dhanashri Jadhav et al. (2022). ‘‘Automated Smart Irrigation System using IoT″. International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET) Vol. 11, Issue 5, May 2022 _ www.ijirset.com