EN 110

Course Project

Smart Farm

An Automated Energy Efficient Farm

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Course: *EN 110 - Fundamentals of Energy Engineering*
Spring Semester 2020 - Indian Institute of Technology Bombay
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Introduction

After the Covid 19 pandemic in 2020 – 21, mass public gatherings are restricted, and social distancing norms are strictly enforced, which has affected most industries in India that require a large number of manual labourers. Especially the large area plantation farms (cashew-nut, coconut, betel-nut, tea, apple, mango orchards). These require many labourers for day-to-day maintenance like irrigation due to the absence of labour (cannot be managed by plot owner alone) are now lying barren or not at total capacity. Common area gardens/terrace gardens of apartment complexes are also not maintained due to lockdown restrictions preventing people from leaving their homes. Also, professionals in the IT sector working from home have their ancestral farmlands barren or under lower capacity. Our project includes designing an adaptive automated IoT enabled farm control system that can be monitored remotely via the internet that can be used to solve the above problems.

Assumed Case Study - Farm Details

1) The agricultural plot is **Rectangular**, Area of the rectangular plot is **150m x 300m ~ 11 acres**

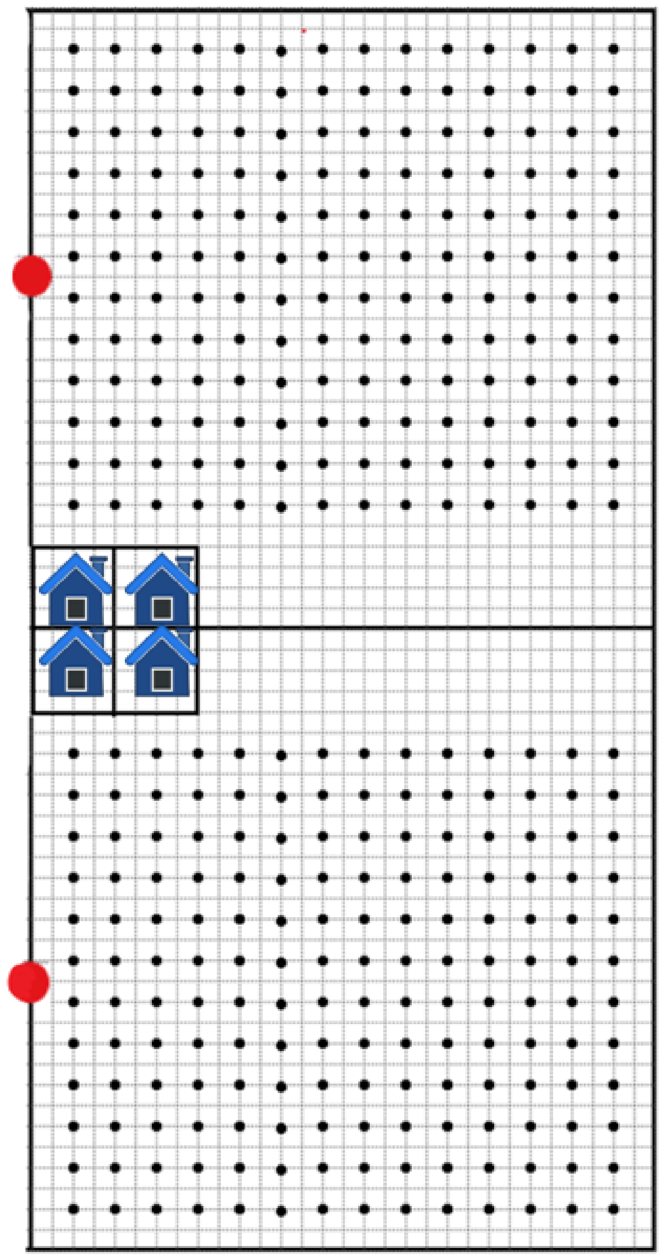


Fig 1.1 - It depicts the chosen farmland, the coconut trees are the **bold black dots** and the **red circles** situated equidistant from the central axis are the wells.The **4 squares containing the blue house icons is the owner's personal usage land.**

2) At the center there is the owner’s house, godown, area for personal usage of square dimensions of **40m x 40m ~17200 sq ft** .

3) The plantation only has **coconut trees**, and is dependent on **rainfall** and **manual labour** to carry water in **back carryable hose sprayers** that is filled from a water tank that pumps water from underground wells and doesn’t have any automated irrigation systems beforehand.

4) There are **two main coconut groves** on two of the halves of the land each having **12 rows** and **14 columns** of coconut trees. Thus **168 coconut trees per grove**. Total **336** coconut trees

5) Spacing between each coconut tree is **10m**. This allows sufficient space for the roots of coconut trees to **prevent survivalistic competition for space** between coconut trees. It also allows **access to transport vehicles to carry the harvested coconuts**.

6) Area of each square in the above grid of **5m x 5m ~ 25 sqm**

7) Assuming that there is a rainwater sourced well with **sufficient perennial supply** of water situated equidistant from the owner’s house on the vertical axis. (shown as red circles in the figure above)

Automated Irrigation System For a Coconut Grove

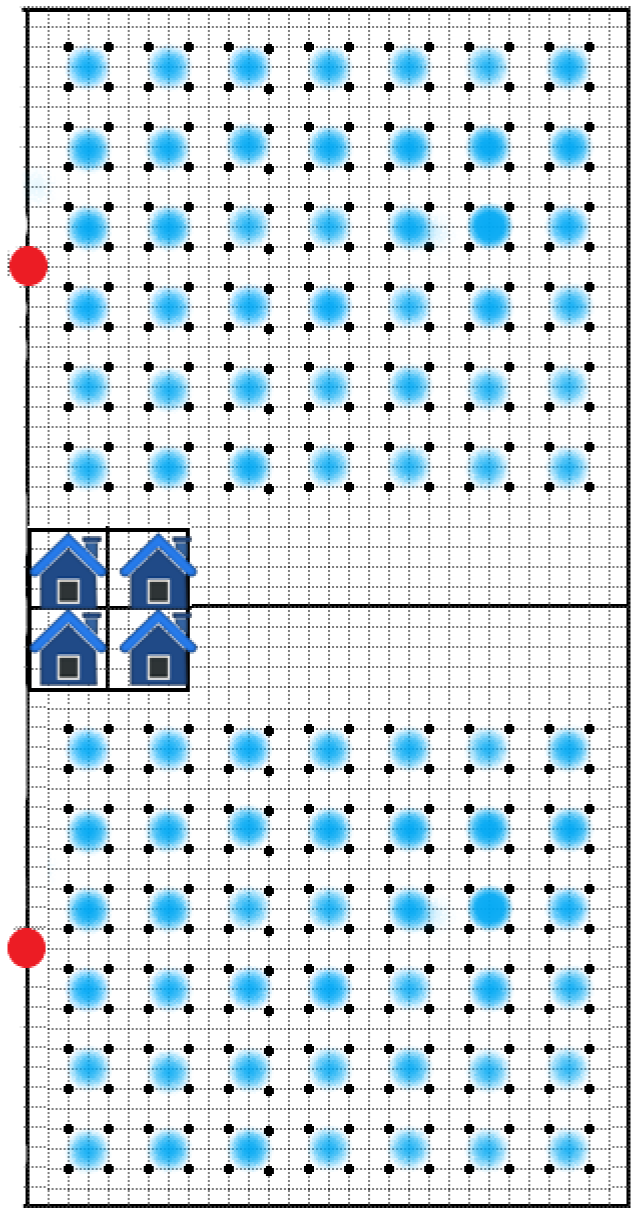


Fig 1.2

Fig 1.2 - It depicts the positioning of the sprinklers and the **blue region depicts the reach of the sprinklers**. The sprinklers must thus be placed **at the geometric center of the alternate squares** formed by the coconut trees. To optimize the water usage by the coconut trees.

Choice of Sprinkler Nozzles

Since from above, we need **1 sprinkler for 4 trees** at the center of the square, the radius of the wetted diameter is $5\sqrt{2}$m and accounting for real world parameters and not cutting the corners, we take it to be **8 - 8.5 m.**

MEGANET™ 24D

NOZZLE SIZE (MM)	CODE COLOUR	WORKING PRESSURE (BAR)	FLOW RATE (L/H)	WETTED DIAMETER (M)
1.85	Yellow	2.5	210	11.0
		3.0	230	11.0
2.06	Purple	2.5	258	12.0
		3.0	283	12.0
2.44	Green	2.5	362	14.0
		3.0	396	14.0
2.79	Blue	2.5	461	17.0
		3.0	505	17.0
3.08	Brown	2.5	553	18.0
		3.0	605	18.0

So judging from these data sets, the chosen sprinkler candidate is the **Meganet 24D sprinkler (code color blue)** with a **nozzle size** of **2.79mm.** This would operate with a working **pressure range of 2.5-3 bar** and **flow rate 461-505 L/H**.

With this we must appropriately choose the pump system which would cater to the pressure and flow requirements of the sprinkler system.

Plan of action to operate the sprinkler system

1) The sprinkler system will be broken down into smaller systems of 1 row of coconut trees, with each having an independent control system.

2) At a given point in time in each row of sprinklers only one sprinkler can operate at a time.

3) For each half (approx 6 acres) we will have 6 rows of sprinklers and 1 underground well each. Thus each half farm will have an independent control system.

4) **Assumption -** there is a preexisting 5 HP large pump in both of the two wells to pump the water from the bottom of the well (~100ft - 200ft) to a large storage tank (~1000L) whenever the tank empties. Where earlier the manual labourers would fill the back carryable hose sprinklers to water the plants

Rated Power (HP) : 5 HP
Rated Power (KW) : 3.72 kw
Winding : Copper
RPM : 1440 RPM

5) A custom made water level controller for example https://www.amazon.in/Mivan-Technologies-Automatic-Controller-Indicators/dp/B01N75OF4A can be used for the well, 1000L tank and 5 HP pump system, this will switch on whenever the water level of the tank goes below a certain level and switches off whenever the tank is full.

6) 6 smaller pumps per half of the farm will be needed for each row to pump water from the tank to 1 sprinkler at a time. Hence 0.5 - 1 HP pumps should be ideal for this.

Motor Horsepower	0.5-1 HP
Pressure	1.5 to 3 bar
Flow	500-1000 LPH
Power Source	Electric
Material	Cast Iron (Frame Material)
Phase	Single Phase
Speed	1500-2000 RPM
Voltage	220-240 V

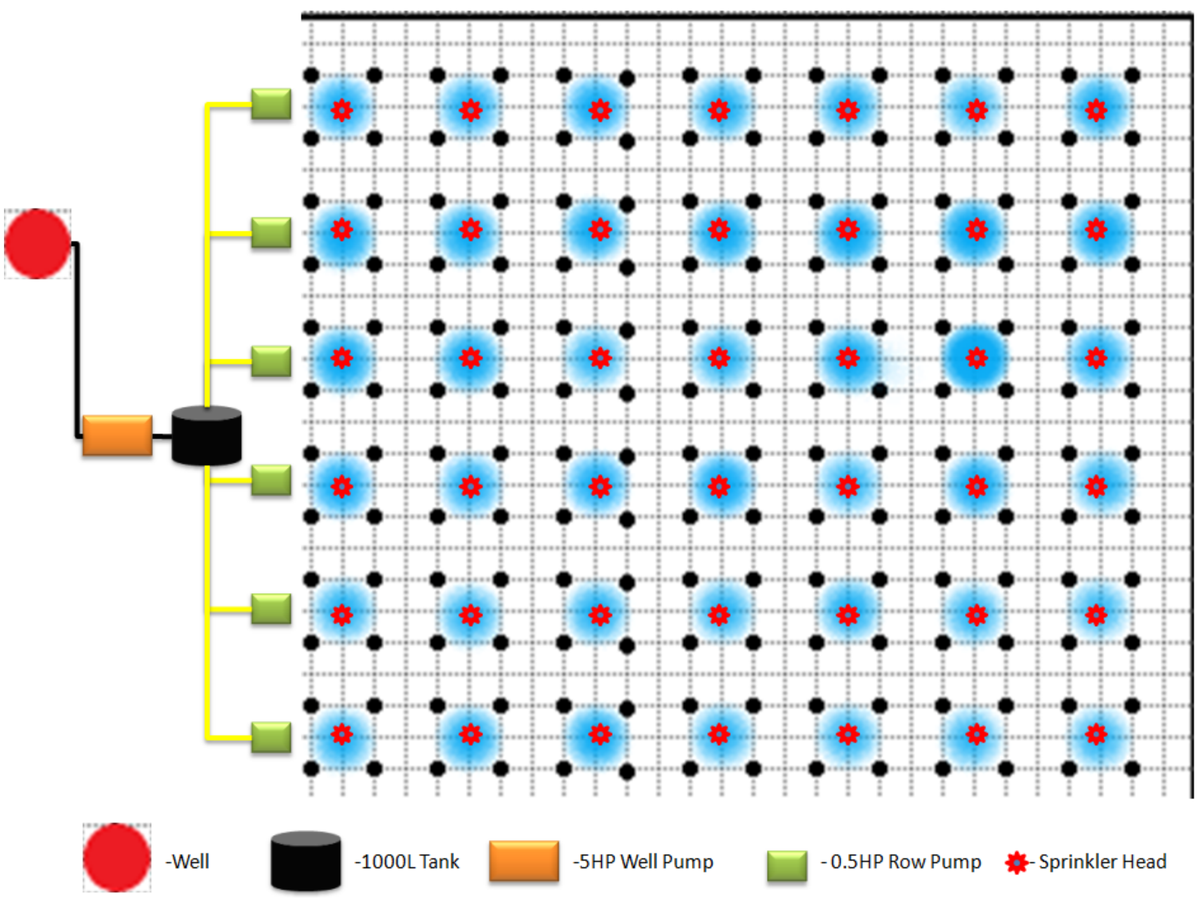


Fig 1.3

Fig 1.3 -The above figure depicts the 1st -6th points of the plan of action (for one half farm). **The underground well is connected to the 1000L tank by the 5HP pump** and **each row of sprinklers is connected to the 1000L tank by 1 pump per row of 0.5-1 HP power.**

7) To switch on each sprinkler at a time we will need **7 - 230V solenoid valves per row** that will switch on and allow water to flow when a control voltage of +5V is given from an external source.

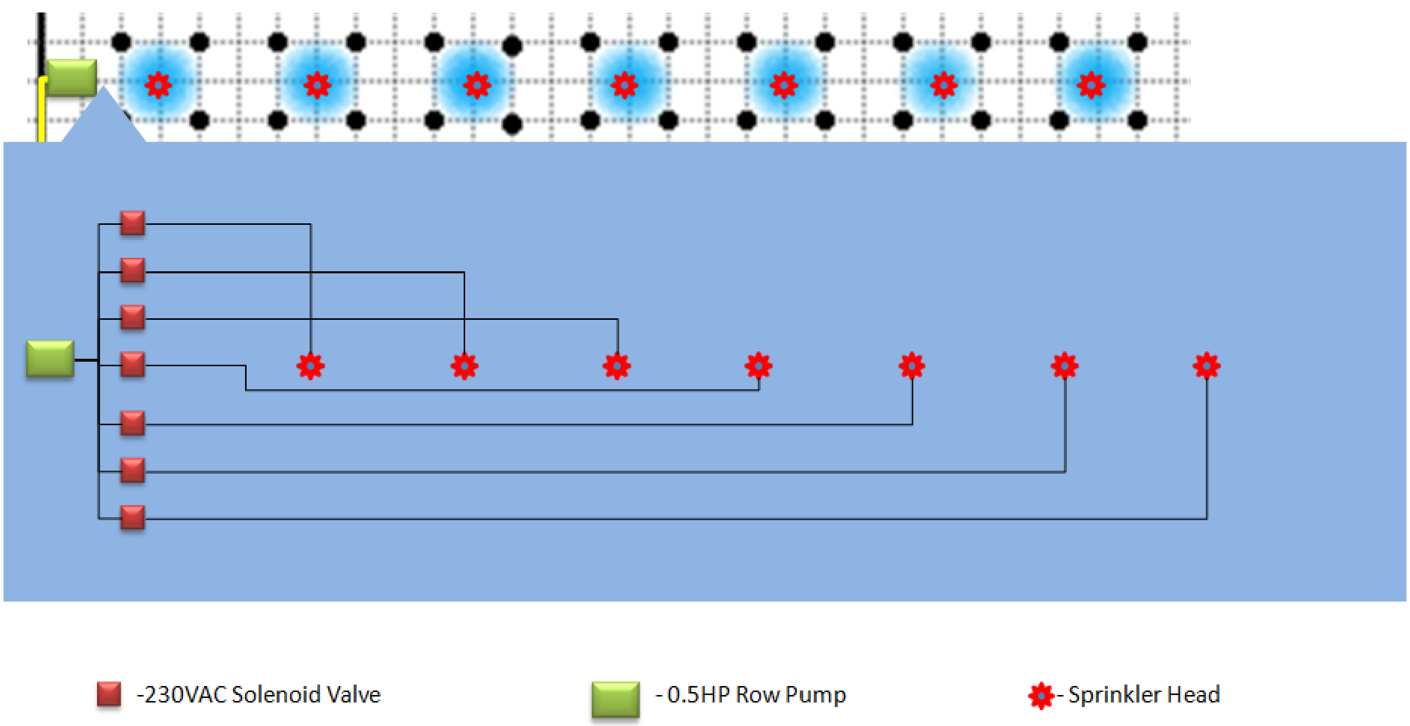
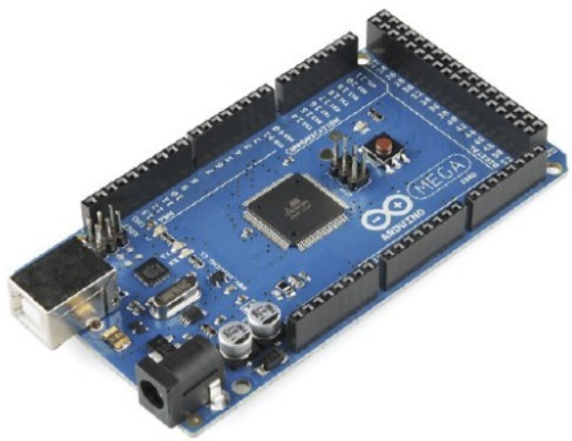


Fig 1.4

Fig 1.4 - The above figure depicts the 7th point of the plan of action. **Each 0.5-1HP pump is connected parallel to 7 230VAC solenoid valves** that are connected to the 7 independent sprinklers. **When a control voltage is supplied to the solenoid valve the solenoid valve will allow water to flow** through the solenoid valve and hence the sprinklers.

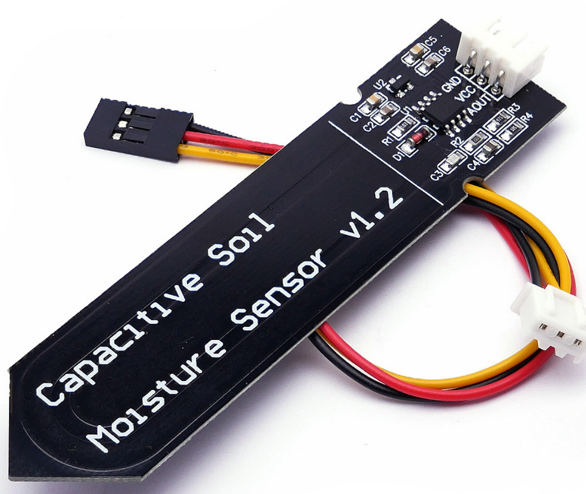
Control System Implementation

1) Components Used for Control System (**per row of sprinklers**)
   a) 1x **Arduino Mega 2560 Microcontroller Board**



   b) 7x **Capacitive Soil Moisture Sensor V1.2 (Soil Hygrometer)** (1 per sprinkler)

It will be positioned at a point at a radial distance of ~$5\sqrt{2}$m from the sprinkler close to a coconut tree, will be pushed into the ground.



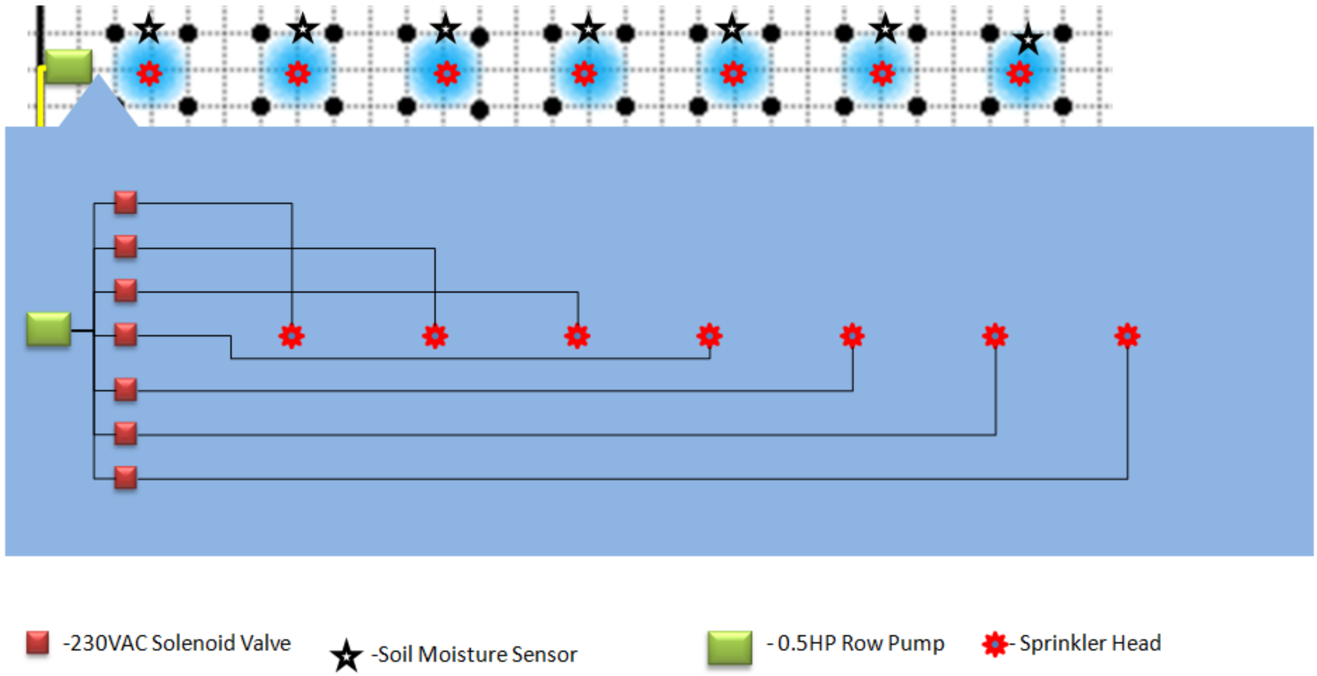


Fig 1.5

Fig 1.5 - The above figure additionally shows the location of the capacitive soil moisture sensors using the star icons as shown

Working of the Capacitive Soil Moisture (Soil Hygrometer)

1) The electrical component known as a capacitor consists of three pieces. A positive plate, a negative plate and the space in-between the plates, known as the **dielectric**.

2) A capacitive moisture sensor works by **measuring the changes in capacitance** caused by the **changes in the dielectric medium** (here the soil).

3) Capacitive measuring has some advantages, It not only **avoids corrosion of the probe** but also gives a better reading of the moisture content of the soil as opposed to using a resistive soil moisture sensor. Since the contacts of the capacitor are not exposed to the soil, there is **no corrosion of the sensor** itself. A resistive soil moisture sensor on the other hand **can corrode in 2-3 weeks** due to **continuous current flow**.

4) The sensor returns an **analog voltage signal (**A DC signal whose magnitude keeps changing**)** that is **linearly dependent on the moisture content in the water**.

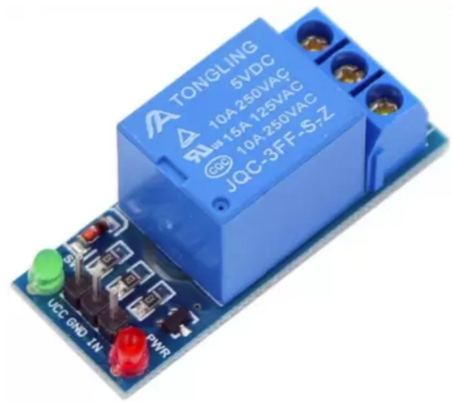
5) The magnitude of the **voltage signal decreases with the increase in the water content** in a **linear** fashion.

6) Thus every plant will have a **threshold voltage depending on its water needs**. If **instantaneous reading is more than the threshold**, the plant will need watering.

7) The following is a link to research done on capacitive soil moisture sensor https://www.researchgate.net/publication/342751186_Capacitive_Soil_Moisture_Sensor_Theory_Calibration_and_Testing

c) 7x - **230VAC Solenoid Valve** (One per sprinkler)

d) 8x (1 for 0.5-1HP pump and 7 for each solenoid valve) - **5V relay switch**

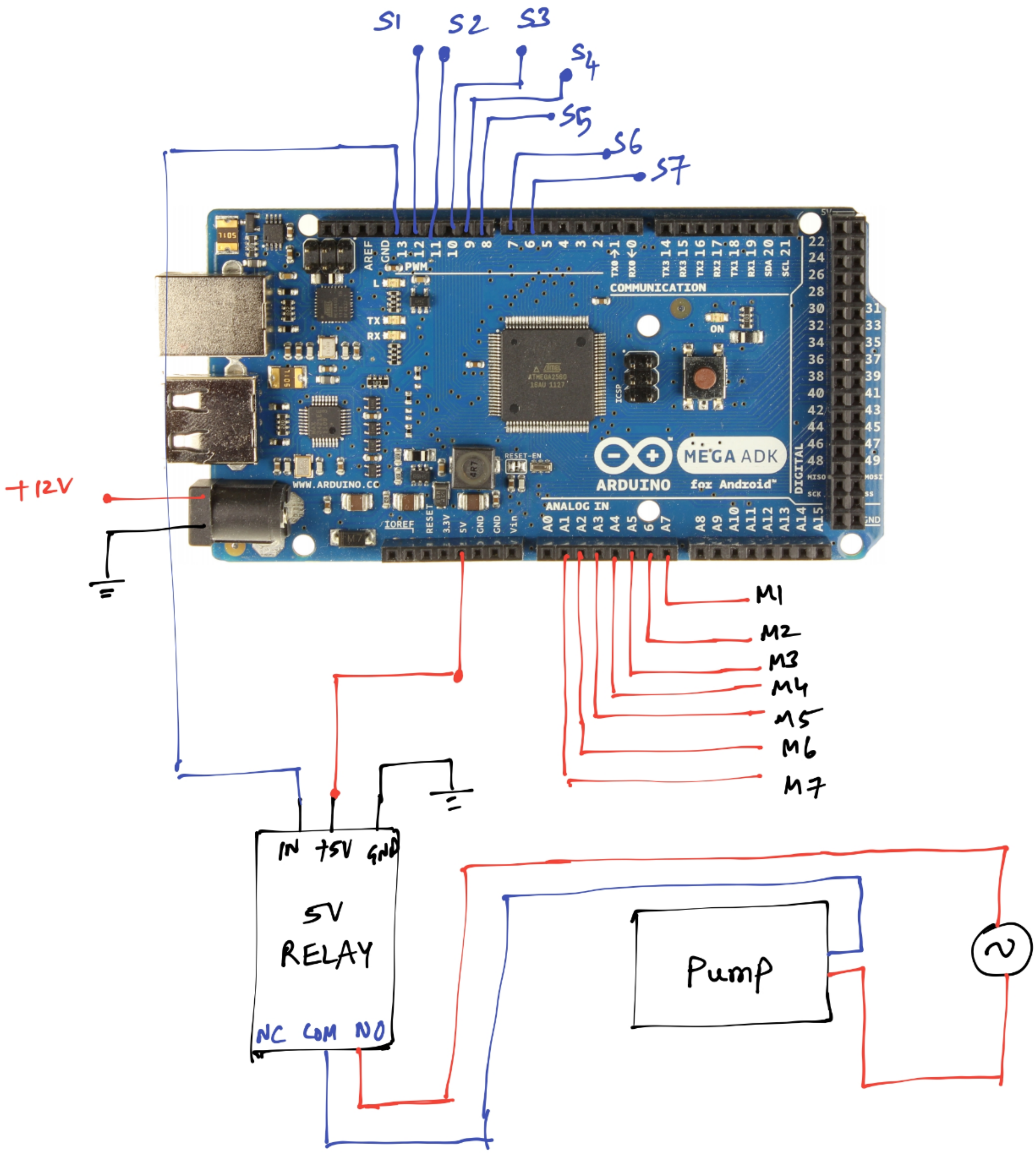


2) Thus each row of the sprinkler system with **7 sprinklers**, **7 moisture sensors**, **7 solenoid valves, 8 - 5V relay switches** will be independently controlled by **1 Arduino Mega Microcontroller Board**

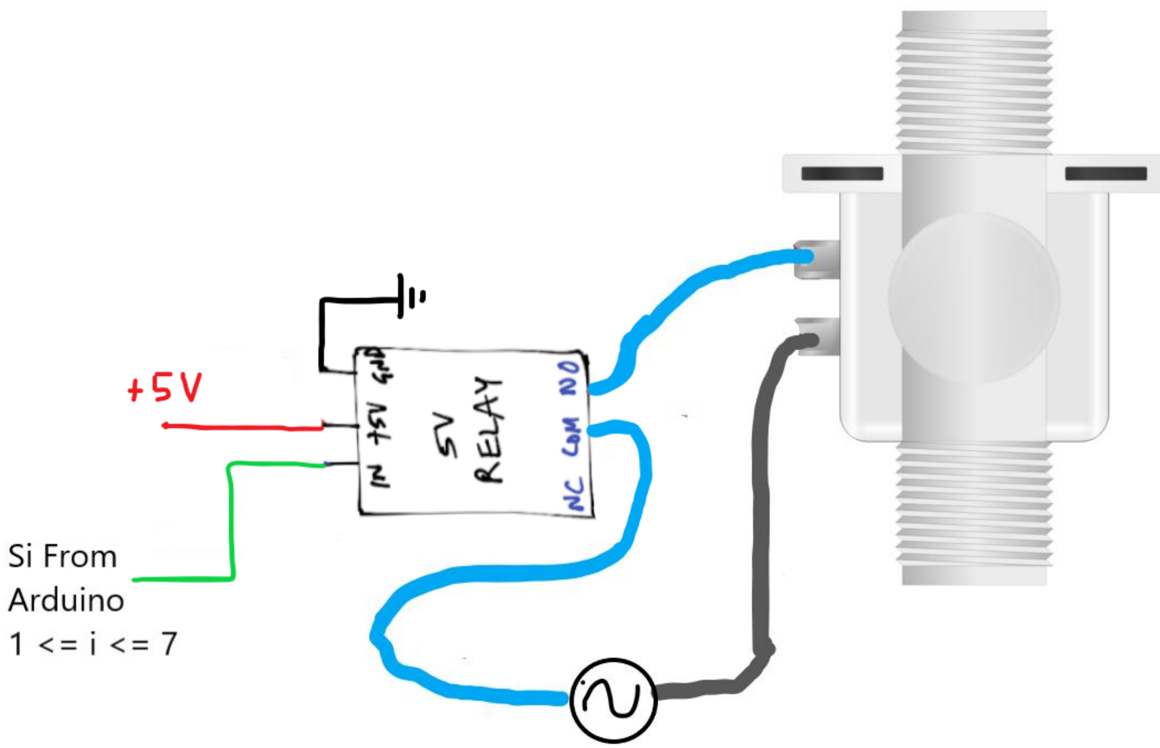
3) There will be **6 such independent rows** per half of the farm.

Circuit Schematics (for each row)

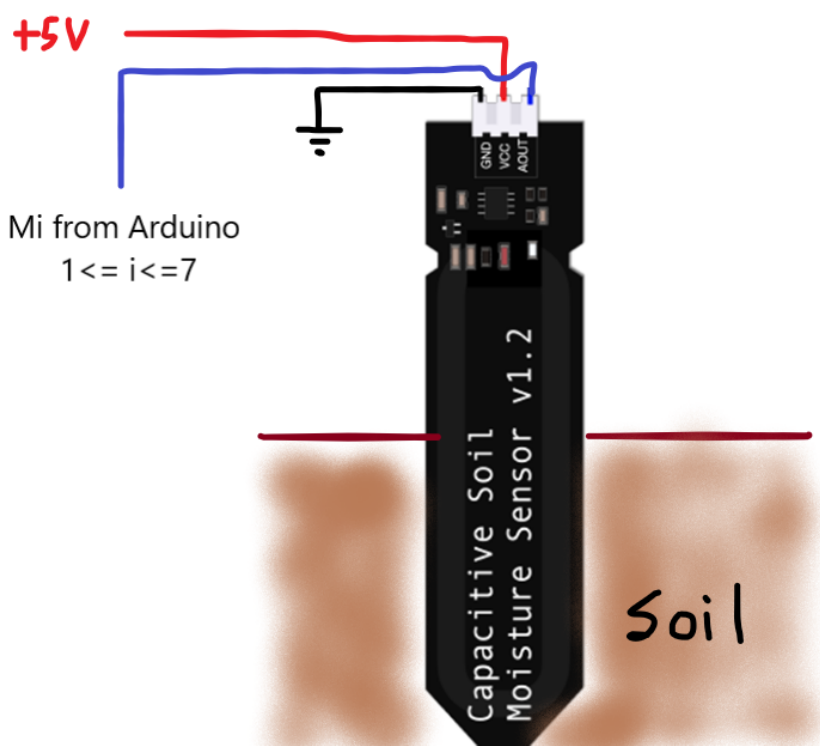
Schematic 1



Schematic 2



Schematic 3



Explanation of Above Circuit Schematic and Connections

1) Each Arduino board will be supplied with external 12V DC supply voltage that can be done using a 230V AC - 12V DC adapter.

2) In Schematic 1, the main circuit diagram of the arduino is visible, we have the **0.5HP pump connected to AC 230V supply voltage via a 5V relay switch.**

3) A digital control pin **(pin #13 of Arduino) is connected to the IN pin of the 5V relay**.

4) Digital **pins #12,11,10,9,8,7,6 are connected to the IN pins** of the 5V relays connected to the solenoids numbered $S_i\,(1 \le i \le 7)$ circuits depicted in Schematic 2.

5) Each **solenoid valve is connected to AC 230V supply voltage via the 5V relay switches** depicted in the previous point.

6) Analog **pins #A1,A2,A3,A4,A5,A6,A7 are connected to the pins numbered AOUT on each Soil moisture sensors** numbered $M_i\,(1 \le i \le 7)$circuits depicted in Schematic 3

7) Similarly all the 5V relays and the moisture sensors can be provided with +5V power supply using AC 230V to DC 5V adapters.

Code Implementation Guidelines

1) We will need to set the $M_i\,(1 \le i \le 7)$connected pins as analog input, which will read the analog readings from the soil moisture sensors **which is linearly related to the amount of water in the soil**.

2) We will need to set the $S_i\,(1 \le i \le 7)$ connected pins as digital output. We will send a **digital HIGH** signal to the 5V relays whenever we need to switch on a particular solenoid valve.

3) Since this control system is for 1 row, we will have to make sure that only 1 sprinkler is on at a given time since the pump pressure per row is sufficient to run only one sprinkler at a time.

4) We will implement this in the control system using the **concept of queue data structure (FIFO - first in first out principle)**. The requests to switch on sprinklers will be stored in a queue and will be managed one by one.

5) Since **Arduino IDE does not allow for direct use of a queue data structure** we will need to implement **queue data structure using C++ classes**.

6) Each loop cycle of the Arduino board will have a **sensing part** and a **request completion part**

a) Sensing Part

1) The soil moisture sensor **returns an analog value.** Whenever the **instantaneous moisture reading for a particular sensor is more than a given threshold** (depends on the water needs of the plant and calibration) we need to pass a request to switch on the corresponding sprinkler (by passing a HIGH signal to its solenoid). The request will be pushed into the queue.

2) We will need to **select the correct threshold value for coconut trees** by trial and error such that its **water requirements are met**.

3) Similarly all the 7 moisture sensor readings are compared with the threshold and the queue is updated accordingly.

Calculation of the Threshold - Important Necessary Calibration for Soil Moisture Sensor

1) The capacitive soil moisture sensors are situated at **large distances (~150m)** from the microcontroller board unlike the 5V relays and solenoid valves.

2) The sensor generally returns a **DC analog voltage reading** from 1 - 5V **proportional to the water content in soil** with small enough cables

3) In this case however, there will be some **losses in the magnitude** of analog voltage **due to the resistance of the ~150 m long AWG22 wires** from the moisture sensor to the Arduino board. **AWG22** has a resistance of **~16Ω/300m ~ 0.05Ω/m**. Also as the operating current is **~10-20mA** the drop in potential is very less **(of the order ~0.15-0.5V)** but **leads to variation in ambient readings** for different sensors.

4) We shall perform the following calibration for all sensors during installation. First take the reading in **complete water medium**, take the reading in **complete air medium**. The soil moisture values **must lie in this range** at all times. Then we shall take the reading of the **threshold** which **is the correct amount of water required for the tree**, this should lie between the **complete water medium** and **complete air medium** readings.

5) The value of the threshold **will be different for different sensors hence calibration of the sensors is important**.

b) Request Completion Part

1) The queue requests must now be executed. The **exit condition is when the size of the queue is zero** i.e **when no more requests remain**.

2) As the first request in the queue is taken, **the coconut trees must be watered in such a way that its instantaneous moisture reading goes below the set threshold**. This can be transformed to an **infinite iterative block** with **watering cycles of 30 sec each** after which the moisture reading is compared

with the threshold. **If the moisture level goes below the threshold then the iterative block is broken**.

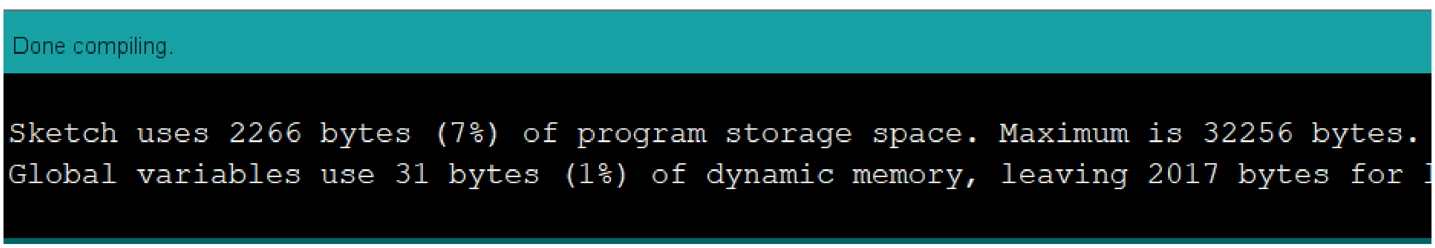
3) The same is repeated for all the pending requests.

7) After both steps **a)** and **b)** are completed. The process is again repeated starting with a) and so on.

Implemented Arduino IDE Sketch Code

The code can be accessed via this github link
https://github.com/rohankalbag/Energy-Efficient-Smart-Farm/blob/main/EN%20Course%20Project%20Arduino%20Sketch.ino

The code was compiled without any errors in the Arduino IDE compiler as shown in the figure below


```
Done compiling.

Sketch uses 2266 bytes (7%) of program storage space. Maximum is 32256 bytes.
Global variables use 31 bytes (1%) of dynamic memory, leaving 2017 bytes for l
```

Requirements of Components for Automated Irrigation System

Name of Component	Quantity of Component
5HP Pump	2
0.5-1HP Pump	12
Sprinkler Nozzles	84
Soil Moisture Sensors	84
230VAC Solenoid Valves	84
Arduino MEGA boards	12

5V relay switches	96
1000L Storage Tank	2
12V adapters	12
5V adapters	168
Water Controller for Well -5HP pump setup	2
Connection Wires (Preferably 22AWG wire) generally Rs 7/m	Sufficiently as required ~5km

Estimation of Energy Costs for Irrigation System

Since it is a control system that switches on whenever the need is required and not always **direct calculations cannot be made,** however **we can assume that the threshold is set in accordance to normal water conditions (best yield) required by the tree and estimate the energy costs**.

1) One coconut tree on average requires the following amount of water for healthy growth.

Months	Normal condition (for best yield)	Moderate water scarcity condition	Severe water scarcity condition
A. Drip irrigation			
February to May	65 lit / day	45 lit/ day	22 lit / day
January, August and September	55 lit / day	35 lit / day	18 lit/day
June and July, October to December	45 lit / day	30 lit/ day	15 lit / day

2) Assuming the situation is mapped to **the normal condition (best yield).** We take the **weighted mean of water needed per day per tree to get average water requirement**

   = (65*4 + 55*3 + 44*5)/12 ~ **54 lit/day**

3) Each sprinkler needs to water **~54 liters of water per day per tree**. Thus per square we need **4*(~54L) = 216L/day per sprinkler** since 4 trees are watered by 1

sprinkler equally. The **set flow rate of the sprinkler is ~500 lit/h**. Hence the sprinkler needs to be on for **~ 0.018 h = 1.08 min/day ~ 65 seconds per day**.

4) Thus the 0.5-1HP pump needs to be turned on for **7*65 = ~455 seconds per day** (since 7 sprinklers are there) .
5) Assuming 1HP pump the energy consumption from this pump per day is **0.746 kW (455s) = 339.5 kJ ~ 0.095 kWh**. There are 12 such pumps hence total power consumption by these pumps is **1.1kWh per day**.

6) Water consumed per day is **54*12*28 lit/day** = **18144 lit/day**. So each half of the farm will consume nearly **9072 lit/day**.
7) Assuming flow rate of 5HP pump to be the average of **500 and 1000 lit/h ~ 750 lit/h**. The time taken by the 5HP pump to pump **9072 lit of water per day is ~ 0.504 h**. Thus each 5 hp pump consumes **5(0.746)(0.504) kWh = 1.88 kWh** per day to pump water from the well to the tank
8) Thus both the 5 HP pumps together consume nearly **3.76 kWh** per day.
9) Thus total energy consumption is **3.76 + 1.1 ~ 4.86 kWh per day**. The control systems consume **very less if not negligible energy** hence **assuming the consumption to be nearly 2% of the total consumption**. The total energy consumed per day is nearly **4.95kWh per day**.

Thus the total energy consumption of the system is nearly 5kWh per day assuming the threshold is set in accordance to normal water conditions (best yield).

Solar Photovoltaic System Accommodations

- The **installed peak load (maximum demand)** of the system is **2*5hp + 12*(1hp) = 22hp ~ 16kW**. The sprinklers are turned on for small durations of nearly 1 minute each hence it is unlikely or less probable for all the devices to be turned on frequently.

- Hence proposing the installation of a **on-grid 10kW solar system** as per the given requirements. If there is a need for more power, this can be taken from the grid.

- The solar PV system will produce, on an average, **40 units per day**, hence sufficing the daily requirement of the farm. Of which only ~5 units will be used by the irrigation system.

- Since the solar system is an on grid type, when necessary the system will take power from the main grid, and when excess power is produced it will give away power to the grid through **net metering,** hence giving a secondary income source to the owner and a zero monthly electricity bill.

- The project will be done in the farms in the state of Karnataka under the jurisdiction of **BESCOM - Bangalore Electricity Supply Company**. Because this offers a features good policy for on grid Solar PV projects where the company pays for the sold units of electricity at a price of **₹ 4/kWh** (without **state capital subsidy**)

Properties of the installed 10kW Solar PV system

Particulars	Description
Solar Power Plant	10 KWp
Solar Panel in Watt	335 Wp
Area required for panels	1000 Sq.ft
Solar Panel Qty	30 nos.
Solar Structure	10 KW
On Grid Solar Inverter	10 KW
MC4 Connector	6 Pair
DC Junction Box	1 Nos
AC Junction Box	1 Nos
DC Cable	90 Mtr
AC Cable	40 Mtr
Space required	1000 sq feet
Solar Accessories	Fasteners, Cable Tie, Crimping Tool, Earthing Kit, Lighting Arrestor
Price	**₹ 4,50,000** including installation

Average Generation	40 Units Per Day.
Warranty	5 years for Complete System.25 years for Solar Panels.
Delivery and Installation	Delivery within 7 days from date of order/Sanction.Installation within 7 days from the date of delivery.
Solar Net-Metering	According to the electricity board(Here, BESCOM).
Govt. Subsidy	Yes, 20% Govt. Subsidy on benchmark cost.

Fig 1.6

Fig 1.6 - A typical 10kW peak solar system

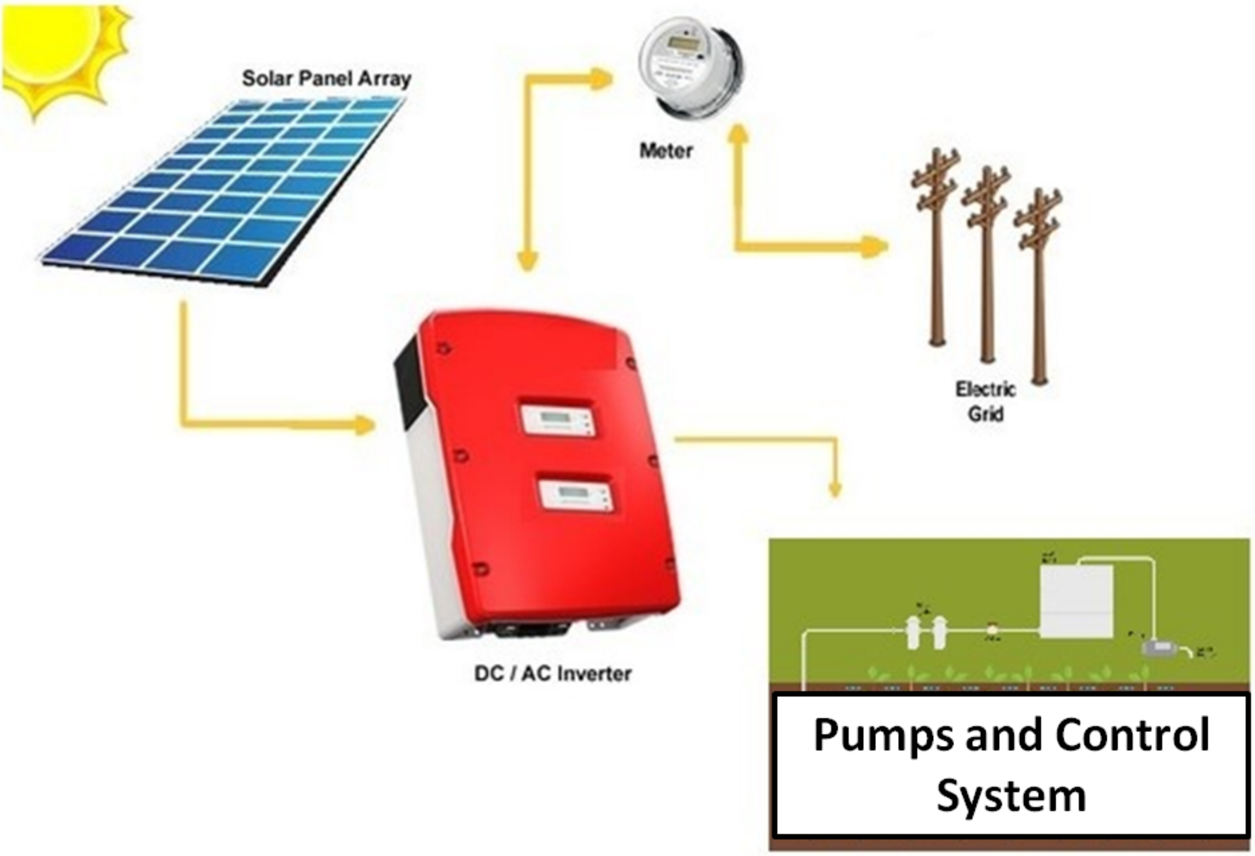


Fig 1.7

Fig 1.7 - Schematic diagram of the solar photovoltaic system showing the typical connections of various components in it.

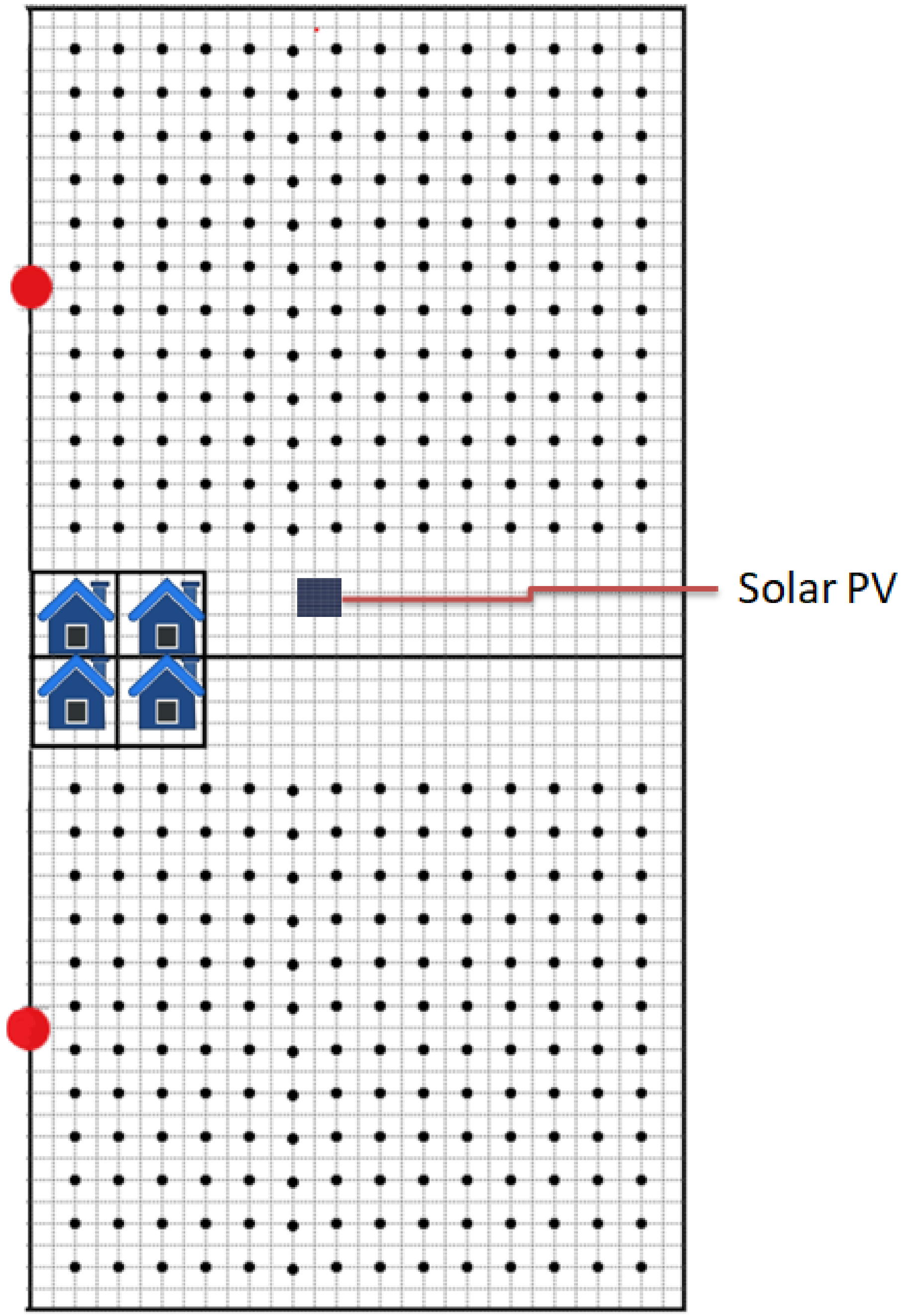


Fig 1.8

Fig 1.8 - It depicts the chosen farmland with a possible location for the Solar PV module which as calculated nearly needs an area of 1000 sq ft which is nearly **~100sqm**

The Economics of the Project

Comparison of the Conventional Irrigation vs Solar PV based Automated Irrigation

Common Capital Costs

(These expenses will be common in both types of irrigation. Hence, **it will not contribute in calculating the Simple Payback Period(SPP)**)

Item name	Links for purchase	Cost (in ₹)	Quantity	Price (in ₹)
5 HP pump	https://www.moglix.com/ksb-5hp-5-stage-three-phase-submersible-pump-uqd-212-5uma-150/mp/msn85806prn492	30,703	2	61,406
1000 L tank	https://www.amazon.in/Sintex-Plastic-Water-Tank-1000L/dp/B01DKCY3WU	2,099	2	4,198

Conventional Irrigation Methods

We assume the **same** field with an area of **11.2 acres** such that the entire farm is planted with coconut trees in both the halves. Assuming the same spacing of 10m between the trees, the **total number of coconut trees** are **2*(12)*(14)= 336**.

Operation and maintenance cost

- Net amount paid to Labourers to irrigate the farm at daily wages of **₹1000** (summation of wages to all labourers) will be **₹3,65,000/ year.**
- As mentioned above, total amount of water consumed per day is **54*336 lit/day** = **18,144 lit/day.**
- In a day, each **5HP pump** will have to extract **18144/2 = 9072 lit.** As it
- pumps out **750 lit/hr,** it needs to be operated for **9072/(750*24) = 0.504 hrs/day**

- Each 5HP pump will consume **5(0.746)(0.504) kWh = 1.88 kWh** per day to pump water from the well to the tank
- Thus, both pumps will together consume **2*(1.88)=3.76 units/day.**
- According to this tariff structure of **BESCOM**. The electricity billing rates are **₹3.85/unit** costing **(3.85)*(3.76)*(365)= ₹5,283.74/year**

Automated Irrigation System

Capital Cost

Item name	Links for purchase	Cost (in ₹)	Quantity	Price (in ₹)
0.5-1 Hp Pressure Booster Pump	https://m.indiamart.com/proddetail/pressure-booster-pump-14795089230.html	14,000	12	1,68,000
Sprinkler Nozzles	https://dir.indiamart.com/search.mp?ss=meganet&prdsrc=1	800	84	67,200
Soil Moisture Sensors	https://robokits.co.in/sensors/water-moisture/capacitive-soil-moisture-sensor-v1.2	160	84	13,440
230VAC Solenoid Valves	https://www.amazon.in/Diaphragm-Agricultulture-Irrigation-Hydroponics-Aquaponics/dp/B07MBMCL9K	390	84	32,760
Arduino MEGA boards	https://www.electronicscomp.com/arduino-mega-2560-r3-india?gclid=Cj0KCQjwzYGGBhCTARIsAHdMTQwaUpswWmR03yZSXElq9fp1L0xrHT5cPHfAXTwNzSXleZZvZAj1KbgaAlSHEALw_wcB	985	12	11,820
5V relay switches	https://www.flipkart.com/rees52-5v-1-channel-relay-micro-controller-board-	146	96	14,016

	electronic-hobby-kit/p/itmf5ks6zjgqh7rb?pid=EHKF5KGUNUQSKFGH&lid=LSTEHKF5KGUNUQSKFGH28EXLJ&marketplace=FLIPKART&cmpid=content_electronic-hobby-kit_8015282045_u_8965229628_gmc_pla&tgi=sem.1.G.11214002.u...395585317613....c.......&ef_id=Cj0KCQjwzYGGBhCTARIsAHdMTQxwIwUgLmI1wNu1M6iu5apk3c1kIQB3B13AVKvaQtIgv4KZ_nYVf1gaAnlWEALw_wcB:G:s&s_kwcid=AL!739!3!395585317613!!!u!297659526158!&gclid=Cj0KCQjwzYGGBhCTARIsAHdMTQxwIwUgLmI1wNu1M6iu5apk3c1kIQB3B13AVKvaQtIgv4KZ_nYVf1gaAnlWEALw_wcB&gclsrc=aw.ds			
12V adapters	Available in general electricals store	200	12	2,400
5V adapters	Available in general electricals store	180	168	30,240
Water level controller module for 5 HP pumps	https://www.amazon.in/Mivan-Technologies-Automatic-Controller-Indicators/dp/B01N75OF4A	2600	2	5,200
Connection Wires (22AWG)	https://www.electronicscomp.com/single-strand-hookup-wire-22awg-red-5metre?gclid=Cj0KCQjwzYGGBhCTARIsAHdMTQzQJOryCUi7Tnc6hUj1fAEBaeW1mO1ps32GQWb3nY0ax4YOpPgweUkaAigfEALw_wcB	7000/km	5 km	35,000

Net Capital Investment for Non Solar Related Automated Irrigation Components : ₹3,80,076

Net Capital Investment for Solar Photovoltaic System: ₹4,50,000

TOTAL CAPITAL INVESTMENT FOR THIS PROJECT: ₹8,30,076

Operation and Maintenance cost

- **Capacitive moisture sensors** need to be replaced after every **3 years**. Hence costing ₹13,440 after every 3 years i.e. **₹4480 every year**. After considering other O and M requirements such as yearly lubrication of pump sets, cleaning of PV panels and piping we assume an average of **₹6000/year** for the annual **O&M costs**.

- Complete dependency on the solar plant would not be possible due to unavailability of sunlight at night time or cloudy days or during peak load hours. Assuming the usage of **4 units** of electricity which will be fulfilled by the solar plant in the **daytime** and the remaining **1 unit** used in **night-time** will be purchased from the grid at the rate of **₹3.85/unit** which will cost (3.85)*(365)= **₹1405.25/year.**

Revenue through net metering of excess energy into the Grid

- Out of **40 units** produced in a day by the Solar PV system, **4 units** are consumed whereas **36 units** are put into the grid and **sold** at a rate of **₹4/unit (BESCOM rates)** hence earning (4)*(36)*(365)= **₹52560/year.**

We assume no major change in the yield from the coconut trees in comparison to the conventional irrigation method.

Conventional Irrigation System		
	Cost (in ₹/year)	**Details**
O&M	5,283.74	Electricity bill
	3,65,000	Labour wages

Automated Irrigation System		
	Cost (in ₹)	**Details**
Capital	3,80,076	New system purchase
	4,50,000	Solar plant installation

O&M	6,000/year	Sensors replacement
	1,405/year	Electricity bill
Revenue	52,560/year	Solar energy sold

Simple Payback Period Calculation

Suppose we want the investment made to be paid back in **t years**.

Making use of the calculated data in the tabular column shown above we use the following

old (O&M) > new (capital + O&M - Revenue) over **t years**…

(5283.74t + 365000t) > (380076 + 450000 + 6000t + 1405t - 52560t)

(418248.74t) > 830076

t > **1.98 years**

Hence the **Simple Payback Period (SPP)** of the investment is **~2 years.**

Conclusions Drawn From The Project

- Farms dependent on **manual labour** and **physical supervision** for irrigation can now be irrigated using this **automated irrigation control system**.

- Farms left **barren** or not in **maximum capacity of potential** due to the absence of manual labour due to the **uncertainty of the pandemic** can now be used **optimally**.

- Similar **case by case site planning** can be done to cater to specific farms based on its **location** and **terrain** and the **crop grown**.

- The irrigation data from the Arduino microcontroller can be merged with an **internet of things (IoT) client** and can now be monitored from the **internet remotely from anywhere**.

- Using an **on-grid Solar PV system**, the energy required can be sourced from the panels during the day and from the grid at night. The **net metering becomes the primary source of income** from the farm even when the **crop yield remains the same**.

- The **daily wages which were the major expenses** in conventional methods can now be **eliminated**. The capital cost of the irrigation system without the solar plant is comparable to the **wages paid to the labourer in a whole year** and **hence very profitable**.

- Though the **initial capital investment is very high**. This can be invested into by large scale farm owners who own large plantations whose production has been affected by the pandemic. The project is **economically feasible** and a **profitable investment for the farm owner** with a **very healthy simple payback period of nearly 2 years**.

Scope for Improvements in Upcoming Designs

1) The installed pumps 5 HP for the wells may be of a **higher rating than required**. After practically checking and **considering the exact contributions of various real-life problems such as pipe friction**, whether the pressure is more or sufficient for pumping up the water in the well if needed, **pumps of lower rating can be installed to make the system more efficient**.

2) Similarly, the 1 HP for each row may be of a **higher rating than required**. Since we have not practically tested this in the field and since the distance of the farthest sprinkler is ~150 m, and **there is a possible loss of pressure from friction in the pipe, we have taken pumps of a higher rating**. After practical verification, if needed, **pumps of lower rating can be installed to make the system more efficient**.

3) The **wiring and circuitry** of the control system can be made more **compact and durable,** and **AWG 22** wiring for the **soil moisture sensors** can be replaced with **CAT4** or **optical fibre technology** to make the sensors more **substantial** and **responsive**.

4) Another option can be offered to the farm owner to **cut down capital costs**. Instead of **turning on one sprinkler at a time, we can merge a row of sprinklers to turn on at the same time**. This alternative will reduce the number of **solenoid valves, relays switches, sensors** and **pumps** as more or less a row of trees will have the same water levels.

Annexures

Acknowledgements

1) **Professor S.B Kedare**, **Instructor** for **EN 110**, for giving us this opportunity and supporting us by introducing the topic of solar PV, control systems and economics in lectures, answering various doubts, queries and providing various sources of reading material.

2) **Aryan** and **Varad**, **TAs** for **EN 110**, for clarifying doubts and queries regarding this project.

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