Sizing, Dynamic Modelling and Control of a Solar Water Pumping System for Irrigation

Master of Engineering Seminar
By
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Tuesday, May 22nd, 2018
OUTLINE

- Introduction
- Literature Review
- Selected Site Data Analysis and System Sizing
- Dynamic Modelling and Simulation in Simulink
- Sensitivity and Effectiveness Analysis
- Design of Instrumentation and Control System
- Conclusions and Recommendations for Future Work
INTRODUCTION

➢ Irrigation is highly significant for crop production
➢ Diesel engine system is costly solution in off-grid areas
➢ Demand for freshwater in increasing rapidly
➢ Conservation of water is also important
➢ Solar water pumping system is widely used renewable source application
➢ The technology of solar cell is growing fast
➢ Solar PV system offers unattended operation, low maintenance, easy installation, long life and causes no pollution
➢ Governments of developing countries have various policies to promote alternative source of energy

Automated Solar Irrigation Pumping System may be an feasible solution
Introduction

Case Study

- Bangladesh - an agriculture-based developing country
- Main crop – rice
- Land under irrigation – 59%
- Ground water irrigation – 85%
- Main power source - electric power & diesel engine
- Electric power – limited access
- Diesel engine – impacts country’s economy
- Average solar radiation:
  - in normal days- 4.0 to 6.5 kWh/m²/day
  - in bright sunshine- 6.0 to 9.0 kWh/m²/day
- Projects:
  - Governmental
  - Non-Governmental
- Government policy:
  - subsidies
  - lower bank loan interest rate
LITERATURE REVIEW

- Anis and Nour [1994], Argaw [1994], Loxsom and Veroj [1994], Katan et al. [1996], Hoque [2001], Pande et al. [2003], Cuadros et al. [2003], Zvonimir and Margeta [2006], Forero et al. [2006], Odeh, Yohanis, and Norton [2006], Hamidat and Benyoucef [2007], Meah, Ula, and Barrett [2008], Bakelli, Arab and Azoui [2011], Mokaddem et al. [2011] worked on system sizing and modelling of solar water pumping system.

- Dynamic modeling and simulation of the solar PV system was done by Gad [2009], Akihiro Oi et al. [2009], Malla, Bhende, and Mishra [2011].

- Yunseop, Evans, Iversen [2008], Dursun and Ozden [2011], Prisilla [2012], Uddin et al. [2012], Li [2013], Pavithra and Srinath [2014], Harishankar [2014], Hussain [2015] provided solutions for automated solar PV system.

- The systems were economically analyzed by Pande et al., Kim, Mahir, Harishankar, Hossain, Hassan, Mottalib, Hossain.
Selected Site

- Name – GS-Gorol project
- Location – Gorol (Kamlertari), Kaliganj, Lalmonirhat, Bangladesh
- Geographical Location – 26°N, 89.28°E
- Installed by – Grameen Shakti
- Technical Support – Sherpa Power Engineering Limited
- Average water discharge - 1700 m³/d
- Total dynamic head – 12 m
- Solar PV – 26.775 kWp
- Motor capacity – 15 kW
- Water tank size – 3400 L
SELECTED SITE DATA ANALYSIS AND SYSTEM SIZING

Site Output Data

**Daily Water Discharge Rate**

- Hourly water discharge (cubic meter/hour)

**Daily Water Discharge by Months**

- Monthly water discharge (cubic meter/day)
## Cost Breakdown of GS-Gorol Project

### Cost Breakdown

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Price (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Panel</td>
<td>21142.59</td>
</tr>
<tr>
<td>Solar Pumping system</td>
<td>16656.45</td>
</tr>
<tr>
<td>Water tank</td>
<td>740.29</td>
</tr>
<tr>
<td>Fixed costs</td>
<td>20974.79</td>
</tr>
<tr>
<td>Others</td>
<td>3207.91</td>
</tr>
</tbody>
</table>

**Total Cost:** 20974.79

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**Notes:**
- Fixed costs include professional fees, installation, and permits.
- Others may include miscellaneous expenses.

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**SELECTED SITE DATA ANALYSIS AND SYSTEM SIZING**
Proposed Solar Irrigation Pumping System

- HOMER - Hybrid Optimization and Multiple Energy Resources
- HOMER Optimization tool – gives feasible solution of battery based system
- Battery less system – manual calculation of tank size equivalent to battery storage
- Load input into HOMER – Daily load data was calculated from the site data
Solar GHI Data

### Hourly GHI Data

<table>
<thead>
<tr>
<th>Hour</th>
<th>Irradiance (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00</td>
<td>399</td>
</tr>
<tr>
<td>9:00</td>
<td>612</td>
</tr>
<tr>
<td>10:00</td>
<td>787</td>
</tr>
<tr>
<td>11:00</td>
<td>901</td>
</tr>
<tr>
<td>12:00</td>
<td>941</td>
</tr>
<tr>
<td>13:00</td>
<td>906</td>
</tr>
<tr>
<td>14:00</td>
<td>796</td>
</tr>
<tr>
<td>15:00</td>
<td>625</td>
</tr>
<tr>
<td>16:00</td>
<td>414</td>
</tr>
<tr>
<td>17:00</td>
<td>170</td>
</tr>
</tbody>
</table>

### Daily GHI Data

<table>
<thead>
<tr>
<th>Month</th>
<th>GHI (kWh/m²/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>3.985</td>
</tr>
<tr>
<td>February</td>
<td>4.447</td>
</tr>
<tr>
<td>March</td>
<td>5.254</td>
</tr>
<tr>
<td>April</td>
<td>5.617</td>
</tr>
<tr>
<td>May</td>
<td>5.469</td>
</tr>
<tr>
<td>June</td>
<td>4.626</td>
</tr>
<tr>
<td>July</td>
<td>4.041</td>
</tr>
<tr>
<td>August</td>
<td>4.164</td>
</tr>
<tr>
<td>September</td>
<td>3.992</td>
</tr>
<tr>
<td>October</td>
<td>4.694</td>
</tr>
<tr>
<td>November</td>
<td>4.182</td>
</tr>
<tr>
<td>December</td>
<td>3.81</td>
</tr>
</tbody>
</table>
**Homer Simulation Result for Battery Based system**

### System Component

<table>
<thead>
<tr>
<th>System component</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV [kW]</td>
<td>38.4 (310 Wp each)</td>
</tr>
<tr>
<td>Battery Storage [No]</td>
<td>60 (12V, 200 Ahr each)</td>
</tr>
<tr>
<td>Inverter [kW]</td>
<td>20.7</td>
</tr>
</tbody>
</table>

![Cash flow Summary chart]

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**SELECTED SITE DATA ANALYSIS AND SYSTEM SIZING**
### Economic Cost Breakdown

<table>
<thead>
<tr>
<th>Component</th>
<th>Capital (US$)</th>
<th>Replacement (US$)</th>
<th>O&amp;M (US$)</th>
<th>Salvage (US$)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV</td>
<td>55,242</td>
<td>4,977</td>
<td>1,876</td>
<td>-2,318</td>
<td>59,777</td>
</tr>
<tr>
<td>Battery Storage</td>
<td>42,000</td>
<td>21,513</td>
<td>0</td>
<td>-554</td>
<td>62,960</td>
</tr>
<tr>
<td>Inverter</td>
<td>14,003</td>
<td>3,193</td>
<td>1,174</td>
<td>-410</td>
<td>17,959</td>
</tr>
<tr>
<td>Other</td>
<td>7,000</td>
<td>0</td>
<td>9,077</td>
<td>0</td>
<td>16,077</td>
</tr>
<tr>
<td>System</td>
<td>118,245</td>
<td>29,683</td>
<td>12,127</td>
<td>-3,282</td>
<td>156,773</td>
</tr>
</tbody>
</table>

Total Net Present Cost (NPC) of the system: US$156,773
The levelized Cost of Operation (COE): US$0.442/kWh
Total operating cost: US$4,245/yr
SELECTED SITE DATA ANALYSIS AND SYSTEM SIZING

Homer Simulation Result for Battery Based system

Monthly average electric production

PV output
SELECTED SITE DATA ANALYSIS AND SYSTEM SIZING

Homer Simulation Result for Battery Based system

Battery Storage

Inverter output
SELECTED SITE DATA ANALYSIS AND SYSTEM SIZING

Battery Less System
Water Tank Equivalent Battery Storage

Battery ampere hour: 200Ah
Bus voltage: 48V
Number of strings: 15
Total watt-hour = (48 × 200 × 15) = 144,000

Calculation of Total Dynamic Head (THD):
  Elevation head = 15m
  Friction head loss for fittings = 1.71 m
  Friction head loss for pipe = 0.44m
  Total frictional head loss = 2.15m
  Total dynamic head = 17.15m
  Total volume of water needed to be stored in the water tank = 3081 m³

Decided Tank Size : 3100 m³
Cost of the Tank

Size of the tank: (40m × 26m × 3m)
Construction cost: US$ 83,087.06
Land cost: US$ 5000

\[ y = 1752.2x + 34071 \]
MATLAB and Simulink

- MATLAB - fourth-generation programming language developed and introduced by MathWorks in 1984
- Simulink - graphical programming environment for modeling, simulating and analyzing multi-domain dynamic systems also introduced by MathWorks in 1984

Dynamic Modeling

- Dynamic modeling and simulation of both battery based and battery less system
- Dynamic modeling and simulation of combined storage system
- To observe the dynamic behaviors of the system components
- Find out a feasible solution
Irradiance and Temperature

Battery based system

Battery less system
Solar PV array

PV model: Chint Solar (Zhejiang) CHSM6612P-310
Module capacity: 310 Wp
Shunt resistance = 85.7392 ohm
Series resistance = 0.44015 ohm
Diode saturation current = $1.8885e^{-09}$ A
Light-generated current = 9.6521 A
Diode ideality factor = 1.1011
Number of cells connected in series in a module = 72
Motor Pump Set

Machine: asynchronous
Type: squirrel cage induction motor
Configuration: 20 HP, 460 V, 60 Hz
Nominal power: $1.492 \times 10^4$ VA
Mechanical power: $1.492 \times 10^6$ W
Nominal speed of the rotor: 1760 RPM
Mechanical torque input is 8 N.m.

\[
\text{the water discharge rate, } Q = 0.0000214(T_e \times w).
\]

Three-Phase Breaker

- Between inverter and asynchronous machine
- Used for protection purpose
Modelling of Battery-Less System
Modelling of Battery-Less System

Boost Converter

- Switching function model
- Directly controlled by duty cycle
- No PWM
- Duty cycle is 0.8
- Firing pulse are blocked

Inverter

- 3 level bridge block
- 3 bridge arms
- 12 switching device along their antiparallel diodes
- 2 neutral clamping diodes
- IGBT/Diodes used

*PWM: Pulse Width Modulation
Simulation Result Analysis of Battery-Less System

PV Properties

AC and DC Voltage and Current
Simulation Result Analysis of Battery-Less System

- Rotor Speed
- Water Discharge
- Tank Water Level
Simulation Result Analysis of Battery-Less System

Water discharge and tank water level

During five second of operation

- water discharge rate: 0.045 m³/s or 162 m³/h
- Tank water level: 1.74e⁻⁴ m

After eight hours of operation

- water lifted: 1296 m³
- Tank water level: 1 m
Modelling of Battery-Based System
Modelling of Battery-Based System

MPPT Controller (P&O Method)

- MPPT control algorithm adjusts the duty ratio to find out the maximum power point
- Most popular because of its simplicity
- This method faces oscillation and power loss
- Unstable while atmospheric conditions changes rapidly

Parameters for Perturbation and Observation Method

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial value for D output</td>
<td>0.5</td>
</tr>
<tr>
<td>Upper limit for D</td>
<td>0.6</td>
</tr>
<tr>
<td>Lower limit for D</td>
<td>0.45</td>
</tr>
<tr>
<td>Increment value used to increase or decrease</td>
<td>3e-4</td>
</tr>
</tbody>
</table>

*P&O Method: Perturbation and Observation Method*
Modelling of Battery-Based System

Flow Chart of P&O Method
Modelling of Battery-Based System

Battery Storage

- Type: Lead Acid
- Capacity: 3000 Ah
- Nominal voltage: 48 V
- Initial state of charge: 60%

Inverter

- 2 level bridge block
- IGBT/Diodes used
- IGBT/Diodes pairs controlled by firing pulses produced by a PWM generator
- Converter controlled by vectorized gating signal
- Gating signal contains six firing pulses
Modelling of Battery-Based System

**Transformer**

- Type: three-phase step-up
- Primary voltage: 48 V
- Secondary voltage: 460 V
- Connection: Grounded Y – Grounded Y

**Transformer Parameter**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal power (VA)</td>
<td>15e3</td>
</tr>
<tr>
<td>Nominal frequency (Hz)</td>
<td>60</td>
</tr>
<tr>
<td>Primary winding parameters</td>
<td></td>
</tr>
<tr>
<td>Ph-Ph R.M.S. voltage (Vrms)</td>
<td>19.59</td>
</tr>
<tr>
<td>winding resistance (Ohm)</td>
<td>0</td>
</tr>
<tr>
<td>winding inductance (H)</td>
<td>0</td>
</tr>
<tr>
<td>Secondary Winding Parameters</td>
<td></td>
</tr>
<tr>
<td>Ph-Ph R.M.S. voltage (Vrms)</td>
<td>187.77</td>
</tr>
<tr>
<td>winding resistance (Ohm)</td>
<td>500</td>
</tr>
<tr>
<td>winding inductance (H)</td>
<td>500</td>
</tr>
<tr>
<td>Magnetization resistance (Ohm)</td>
<td>inf</td>
</tr>
<tr>
<td>Magnetization Inductance (H)</td>
<td>inf</td>
</tr>
</tbody>
</table>
Simulation Result Analysis of Battery-Based System

PV Properties

DC Voltage and Current
Simulation Result Analysis of Battery-Based System

Battery Storage

Transformer
Inputs and Outputs
DYNAMIC MODELING AND SIMULATION IN SIMULINK

Simulation Result Analysis of Battery-Based System

Rotor Speed

Water Discharge and Tank Water Level
Simulation Result Analysis of Battery-Based System

Water discharge and tank water level

During five second of operation

- water discharge rate: 0.05 m$^3$/s or 180 m$^3$/h
- Tank water level: 4.24 e$^{-4}$ m

After eight hours of operation

- water lifted: 634.4 m$^3$
- Tank water level: 0.61 m

Excess energy stored as electrical form in battery storage
Modelling of Proposed System

• Combined storage system
• Configuration almost same as battery based system except the energy storage

Battery storage : 1400 Ah  
Water tank Storage : 660 m³

Advantages:
• User has both energy storage in electrical form and stored water in a water tank for later use
• If any fault occurs in the system, the user can handle the emergency with back-up stored water

Proposed system may give the most feasible solution
DYNAMIC MODELING AND SIMULATION IN SIMULINK

Modelling of Proposed System
Simulation Result Analysis of Proposed System

PV Properties

DC Voltage and Current
Simulation Result Analysis of Proposed System

- Battery Storage
- Transformer
- Inputs and outputs
Simulation Result Analysis of Proposed System

Rotor Speed

Water Discharge and Tank Water Level
Simulation Result Analysis of Proposed System

Water discharge and tank water level

During five second of operation
- water discharge rate: 0.05 m$^3$/s or 180 m$^3$/h
- Tank water level: 2.00826 × 10$^{-4}$ m

After eight hours of operation
- water lifted: 635.8 m$^3$
- Tank water level: 2.89 m

Tank is full at the end of the day
Excess energy stored as electrical form in battery storage
SENSITIVITY AND EFFECTIVENESS ANALYSIS

Sensitivity Analysis

Sensitivity Analysis based on NPC

![Graph showing sensitivity analysis based on NPC with different irradiance levels: 107 kWh/d, 119 kWh/d, and 131 kWh/d. The graph displays the total NPC (US$) against irradiance (KWH/M2/D).]
SENSITIVITY AND EFFECTIVENESS ANALYSIS

Sensitivity Analysis

Sensitivity Analysis based on COE

COST OF ENERGY (US$/KWH/D)

IRRADIANCE (KWH/M2/D)

- 107 kWh/d
- 119 kWh/d
- 131 kWh/d
SENSITIVITY AND EFFECTIVENESS ANALYSIS

Sensitivity Analysis

Sensitivity Analysis based on Operating Cost

![Graph showing Sensitivity Analysis based on Operating Cost](image)

- Operating Cost (US$/YR)
- Irradiance (KWh/M2/D)

- 107 kWh/d
- 119 kWh/d
- 131 kWh/d
Effectiveness Analysis

Cost Breakdown of Battery Based System

FOR ONE 1 OF PERIOD (US$)

- PV: 26,515
- Inverter: 2,805
- Other: 7,909
- Battery Storage: 13,864

FOR 25 YEARS OF PERIOD (US$)

- PV: 59,777
- Inverter: 17,959
- Other: 16,077
- Battery Storage: 62,960
Effectiveness Analysis

Cost Breakdown of Battery Less System

FOR 1 YEAR OF PERIOD (US$)
- Water Tank: 83,087
- PV: 26,515
- Inverter: 2,805
- Other: 7,909

FOR 25 YEARS OF PERIOD (US$)
- Water Tank: 83,587
- PV: 59,777
- Inverter: 17,959
- Other: 16,077
Effectiveness Analysis

Cost Breakdown of Proposed System

FOR 1 YEAR OF PERIOD (US$)

- PV: 26,515
- Inverter: 2,805
- Other: 7,909
- Battery Storage: 7,184
- Water Tank Storage: 20,381

FOR 25 YEARS OF PERIOD (US$)

- PV: 59,777
- Inverter: 17,959
- Battery Storage: 36,340
- Other: 16,077
- Water Tank Storage: 20,881
## Conventional Diesel Engine System

### Economic Cost Breakdown

<table>
<thead>
<tr>
<th>Component</th>
<th>Capital (US$)</th>
<th>Replacement (US$)</th>
<th>O&amp;M (US$)</th>
<th>Fuel ($)</th>
<th>Salvage (US$)</th>
<th>Total ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td>25,000</td>
<td>58,204</td>
<td>94,377</td>
<td>204,759</td>
<td>-506</td>
<td>381,833</td>
</tr>
<tr>
<td>Other</td>
<td>7,000</td>
<td>0</td>
<td>6,464</td>
<td>0</td>
<td>0</td>
<td>13,464</td>
</tr>
<tr>
<td>System</td>
<td>32,000</td>
<td>58,204</td>
<td>100,841</td>
<td>204,759</td>
<td>-506</td>
<td>395,298</td>
</tr>
</tbody>
</table>

### Emission

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emission (kg/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td>104,267</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>257</td>
</tr>
<tr>
<td>Unburned hydrocarbons</td>
<td>28.5</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>19.4</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>209</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>2,297</td>
</tr>
</tbody>
</table>
SENSITIVITY AND EFFECTIVENESS ANALYSIS

Comparison Between Alternatives

**Cost for 1 year of period (US$)**

- Battery less system
- Battery based system
- Proposed System
- Diesel engine system

**Cost for 25 years of period (US$)**

- Battery less system
- Battery based system
- Proposed System
- Diesel engine system
Automatic irrigation system can reduce the water wastage

HiGrow sensor module is an effective solution

HiGrow sensor module and water level sensors detects the field conditions and sends the information to the microcontroller

Microcontroller decides when to operate the motor

User gets the information and able to control the system through webserver

There is also option for manual operation
DESIGN OF INSTRUMENTATION AND CONTROL SYSTEM
DESIGN OF INSTRUMENTATION AND CONTROL SYSTEM

ESP32 : introduced by Espressif System

Features:

- Low cost
- Low power system on a chip microcontroller with integrated WiFi
- Dual mode Bluetooth capabilities
- Power saving features
- Compatible with mobile devices and IOT application
- Wide operating temperature range
- Can act as a complete standalone system
- Can be operated as a slave device to a host microcontroller

*IOT: Internet Of Things
Higrow sensor module: Senses the field condition

Features:

- Communicates with cloud application to upload sensor data
- Can be connected to the webserver
- Senses temperature and humidity through DHT11 sensor module
- Capacitive type soil moisture sensor detects the water content in the soil
- Run by a LG 3000mAh battery up to 17 hours
Proposed Control System

- Solar Panel
- Inverter
- Control System ESP32 based
- Temperature
- Humidity
- Soil Moisture
- Soil Moisture Sensor
- Humidity & Temperature Sensor
- Tank Water Level
- Water Tank
- Motor
- Pump
- Water
Working Principle of proposed control System

❑ **ESP32 Microcontroller:**
  - Gets data from sensor units
  - Takes decisions
  - Sends output signal to the relay to control the motor-pump

❑ **Webserver:**
  - HiGrow sensor module connects to a webserver
  - Client can be connected to the webserver through HTTP
  - Returns a web page to the client
  - Two HTML buttons control the motor operation

*HTTP : Hyper Text Transfer Protocol
*HTML : Hyper Text Markup Language
Working Principle of proposed control System

- **Water level Sensor:**
  - Floating type water level sensor
  - Potentiometer reading changes as the water level changes
  - Connected to ESP32 and send information about tank water level

- **Humidity and Temperature Sensor:**
  - ESP32 is connected to DHT11 to read the temperature and humidity
  - Results are routed to pin 22
Working Principle of proposed control System

- Soil Moisture Sensor:
  - Capacitor is electrically connected with two small resistors
  - As the water touches the sensor, the dialectic constant changes
  - As a result the timer runs at different frequency
  - The output RC oscillator of the timer generates a stable analog voltage
  - This voltage detects the moisture content and routes to pin 32
Working Principle of proposed control System

- Control Program:
  - ESP32 control code refereed as sketch
  - The sketch is written in Arduino 1.8.5 environment
  - The sketch is uploaded in ESP32 using Arduino software
  - A built-in LED; connected to pin 13; represents the motor status
  - Field condition and tank water level are being checked continuously
  - If the conditions satisfy, the microcontroller takes necessary step
Design of Instrumentation and Control System

Working Principle of proposed control System

Deciding Tank Water Level

- A 10K potentiometer represents the water level sensor
- Potentiometer reading mapped into tank water level
- Lower limit of the tank: 0 m
- Upper limit of the tank: 3 m
- Lower limit of the potentiometer: 0 ohm
- Upper limit of the potentiometer: 3000 ohm
Deciding Moisture Content limit

- Soil moisture sensor produces output voltage
- An experiment was done for
  - 300 gm engineered soil which had 36.2% moisture content initially
  - Water added to the soil up to 549.6% to make it slurry
  - Output voltage are recorded accordingly

Moisture content of the soil, \( \theta = \left( \frac{W_w}{W_s} \right) \times 100\% \)

where, \( \theta \) = moisture content,
\( W_w \) = mass of the water (g)
\( W_s \) = mass of the soil (g)
Deciding Moisture Content limit

- Output voltage in the air: 3383 mV
- Output voltage in the clear water: 1700 mV
- Lower limit of output voltage in soil: 1572 mV
- Upper limit of output voltage in soil: 3025 mV
- Lower limit of moisture content in soil: 36.2%
- Upper limit of moisture content in soil: 549.6%

After adding more than 200% water, the output voltage of the slurry becomes same as clear water
DESIGN OF INSTRUMENTATION AND CONTROL SYSTEM

Flow Chart of The Proposed Control System

Start

Initialization

Measure Soil Moisture, Humidity, Temperature and Water Level

Soil Moisture <80%

Yes

No

Temperature > 18 °C

Yes

No

Humidity < 60%

Yes

No

Tank Water Level < 2.5m

Yes

Pump OFF

Delay

ON

OFF

Manual ON/OFF Switch

Pump On
Experimental Results

Testing

- Programmed HiGrow sensor module inserted into dry soil.
- Powered from a USB port which was connected to a laptop.
- The IP address was printed on serial monitor of Arduino software.
- IP address navigates to the webserver through any browser.
- Status of dry soil was checked.
- Some water was added to the soil.
- Status of wet soil was checked.
Experimental Results

Webserver Page When Soil is Dry

- Webserver page shows the temperature, humidity, soil moisture content and tank water level before adding water
- User can control the motor operation by pressing the HTML buttons
- Webserver page is requesting the user to run the motor
- If the user is unavailable, the motor will start running automatically after some delay (5 min)
Experimental Results

Webserver Page When Soil is Wet

- Webserver page shows the temperature, humidity, soil moisture content and tank water level after adding water
- User can control the motor operation by pressing the HTML buttons
- Webserver page is requesting the user to stop the motor
- If the user is unavailable, the motor will stop running automatically after some delay (5 min)
CONCLUSIONS

- The immensely low cost automated solar irrigation pumping system is affordable for the marginal farmers in developing countries.
- The system is time saving and ensures lowest water wastage.
- Homer optimization provides a feasible solution for battery based solar PV system for the selected site.
- Manual calculation for water tank equivalent to battery storage was done for battery less system.
- Dynamic modelling in Simulink was done for: (i) battery-less system, (ii) battery-based system and (iii) proposed system.
CONCLUSIONS

- Dynamic modeling provides the dynamic behaviors of the system components
- Dynamic modeling also provides the water discharge rate and the tank water level at the end of the day
- For the longer operational period, the diesel operated engine is the costliest solution and the combined storage system is the most economical solution
- For lowest load demand, Costs (NPC, COE and operational cost) and irradiance have a negative relationship
CONCLUSIONS

❖ The HiGrow sensor module is extremely cheaper than other PLC devices or commercial controller for water pumping system
❖ The capacitive soil moisture sensor is advantageous over resistive sensors
❖ It is highly recommended to test the soil moisture limits and boundary conditions for temperature and humidity before installation of the system
❖ The proposed control system is more convenient as the user can control the whole operation far from the field
RECOMMENDATIONS FOR FUTURE WORK

❖ Control strategy for larger field area with multiple scattered sensor is recommended
❖ Better user interface in local language and with more features
❖ Longer duration dynamic simulation
LIST OF PUBLICATIONS


- Shatadru Biswas, M. Tariq Iqbal, “Dynamic modeling of solar water pumping system with energy storage” 2017 Newfoundland Electrical and Computer Engineering Conference, St. John’s, Canada, NL, 2017


- Shatadru Biswas, M. Tariq Iqbal, “Solar water pumping system control using a low cost ESP32 microcontroller”, 31 Canadian Conference on Electrical and Computer Engineering, Quebec City, Quebec, Canada, 2018
Thank You
Any Question?