Design, Optimization and Analysis of a Solar Water Pumping System for Pakistan

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Outline

- Introduction
- Literature Review
- Research Objectives
- Design and analysis of a solar water pumping system in HOMER
- Dynamic analysis of the proposed solar water pumping system in MATLAB/Simulink
- Design and analysis of a Solar Water Pumping System with Water Tank in HOMER
- Supervisory Control and Data Acquisition (SCADA) for a Solar Water Pumping System
- Conclusion
- Research Contributions
- Future Work
- Publications
- References

Introduction

Overview of Agricultural Scenario of Pakistan

- Pakistan is primarily an agricultural economy
- Agriculture contributes about 22.2% of its overall GDP
- It employs around 42.3% of its overall labor strength

Overview of Water Resources of Pakistan

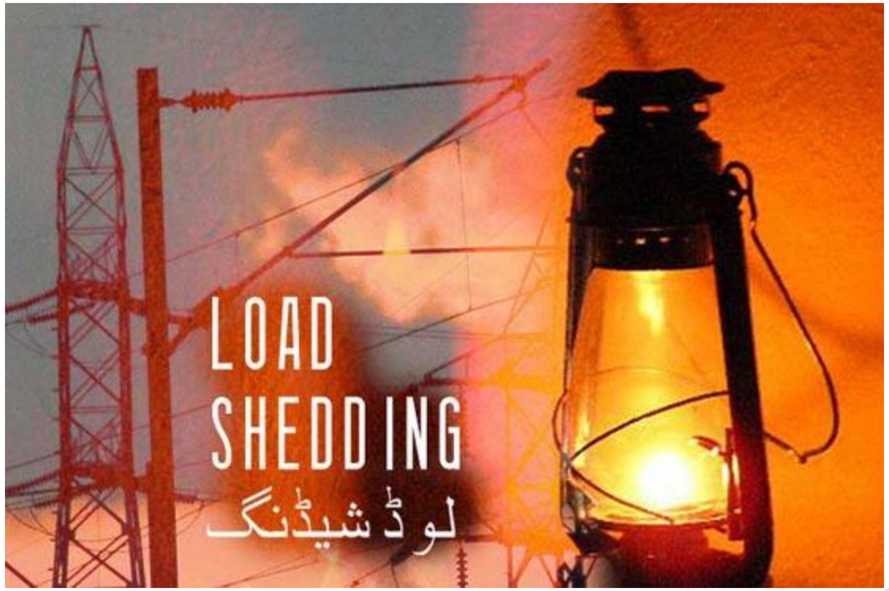
- Water availability was around 5000m^3 per capita in the 1950s
- It has shrunk to around 1000m^3 per capita currently
- By 2025, the water shortfall is expected to reach 150.8 Million acre-feet

Water Pumps installation in Pakistan

- Water Pumps installation is considered a suitable solution to combat increasing shortage of water

Electricity Scenario of Pakistan

- The country's scenario is not ideal as a shortfall of 5,000MW is faced by the country
- Tilt is towards fossil fuels for powering water pumping systems



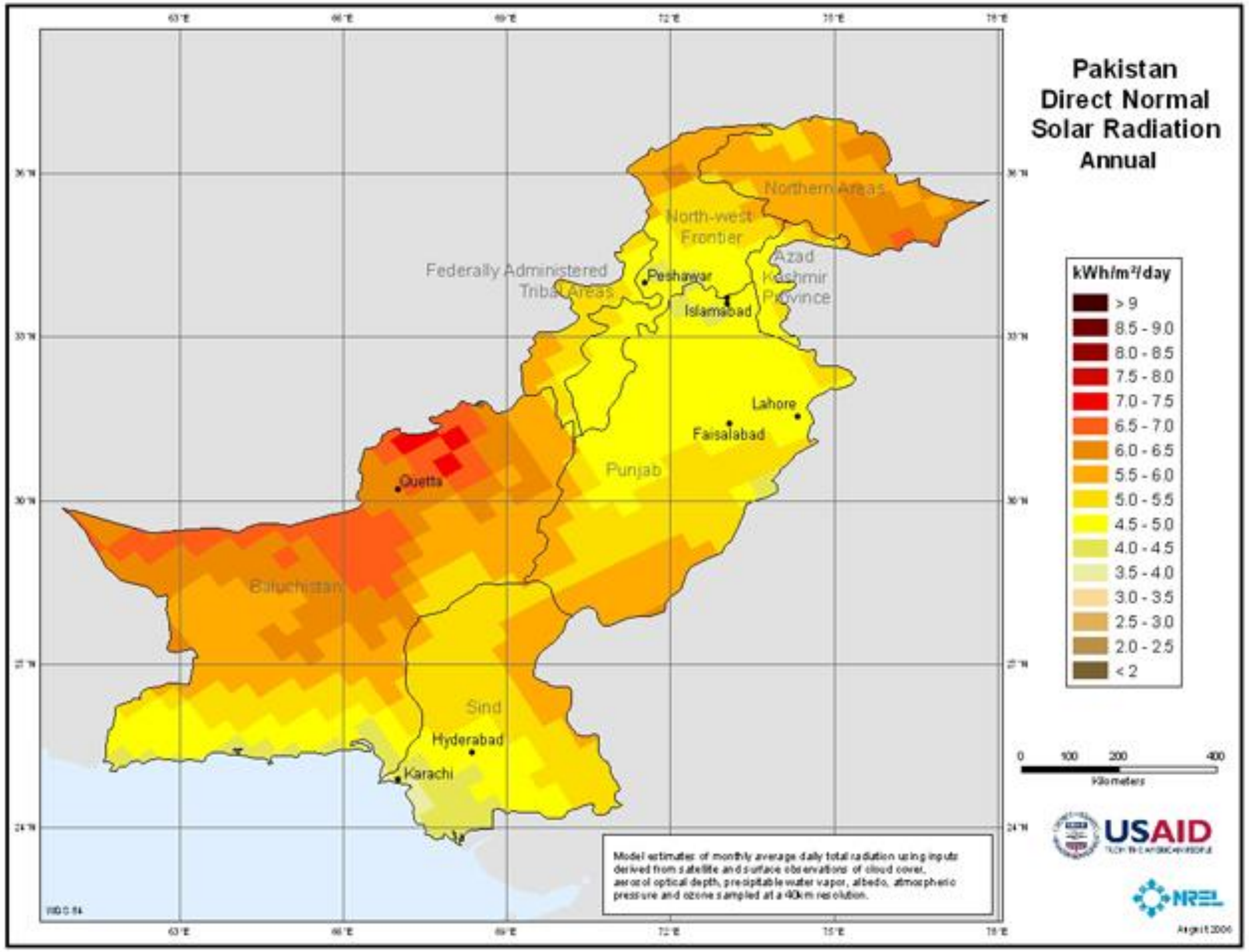
Fossil Fuels Dependence and Pakistan

- Pakistan is not rich in fossil fuels and is primarily not an oil-producing country
- It imports 346,400 barrels of oil on daily basis, which costs a staggering 10.7 billion US dollars to the economy
- Its increased dependence on imported fossil fuel for electricity production has increased the circular debt to 1.2 trillion Pakistani rupees during the period of last five years

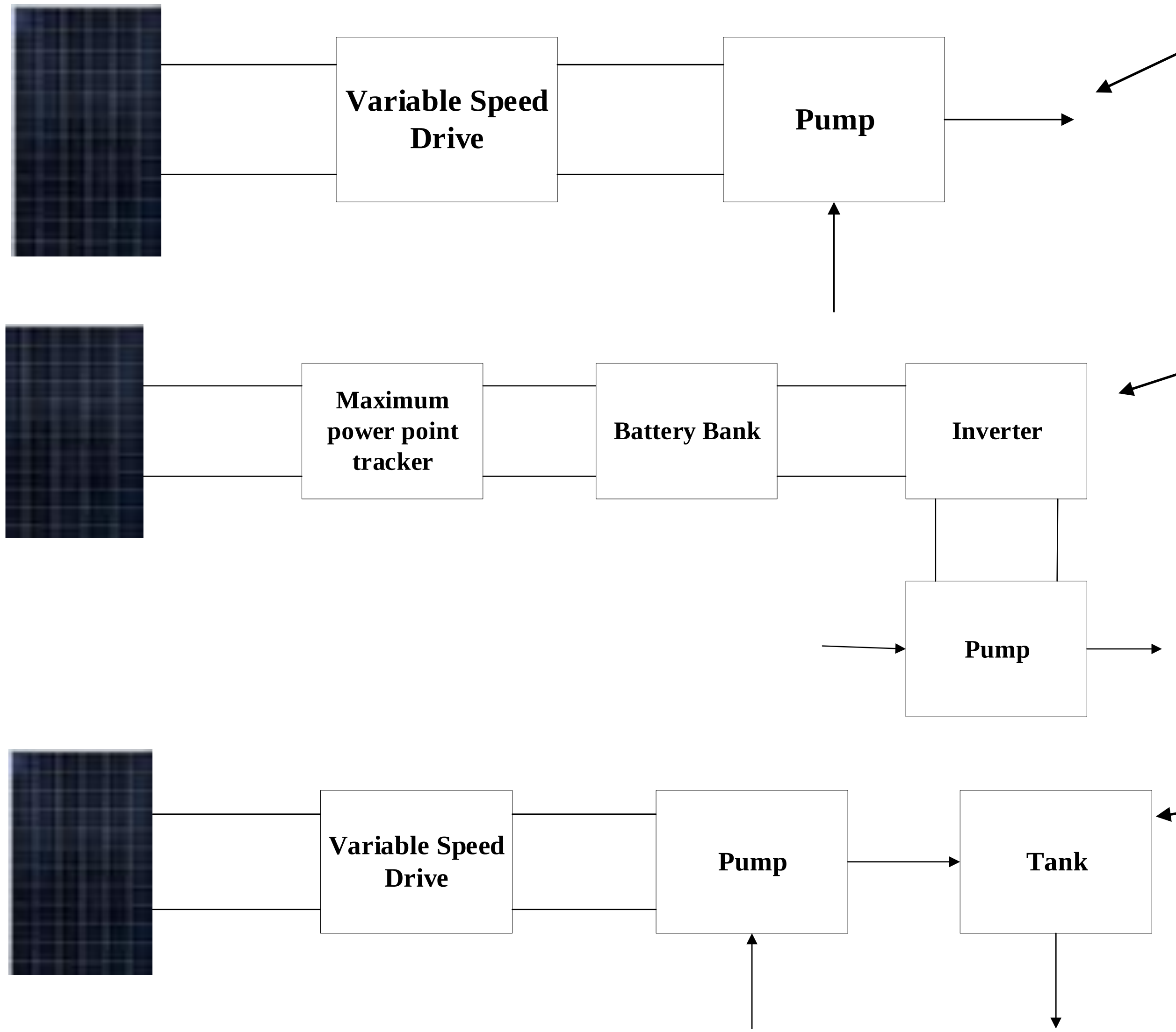
Solar Potential of Pakistan

- There is a massive potential for renewable energy in Pakistan, which is around 167.7 GW
- Among renewable energies, the potential for photovoltaics in particular is immense in the country
- Pakistan is one of the wealthiest countries in terms of its solar potential, which is up to 100,000MW
- The average solar insolation for the country is about 5.5kWh/m^2/day

Solar Potential of Pakistan



Types of Solar Water Pumping Systems



A variable speed drive based solar water pumping system

Battery bank based solar water pumping system

Solar water pumping system with water tank storage

Literature Review

Literature Review

- Literature Surveyed Regarding Solar Water Pumping System design and economic analysis

Paper Reviewed	Comments
P. Chaudhary	Discussed different components, parameters and control methodologies related to a solar water pumping system
A. Allouhi	Discussed sizing and economics of a solar water pumping system
R. Sharma	Discussed optimized design of a solar water pumping system
M. T. Chaichan	Discussed four different designs of solar water pumping system and found PV based solar water pumping system to be the most feasible solution
H. A. Kazem	Discussed designing of a solar water pumping system in Oman
S. Biswas	Discussed a solar water pumping design in HOMER for Bangladeshi conditions
F. Alkarrami	Designed solar water pumping systems using HOMER Pro, HOMER Beta, and iHOGA software and found HOMER Pro as the best option

Literature Review

- Literature Review regarding mathematical modeling of different components of a Solar Water Pumping systems in MATLAB/Simulink

Paper Reviewed	Comments
N. Yadav, T. R. Teregulov, and X. H. Nguyen	Mathematical modeling of PV Panel was discussed in MATLAB/Simulink
M. Assaf and H. Guldemir	Mathematical modeling of Buck-Boost converter was discussed in MATLAB/Simulink
Wen-Yeau Chang, M. Zhang and Low Wen Yao	Mathematical equations for a battery bank were discussed in first two papers and mathematical modeling for a battery in MATLAB/Simulink was discussed in the 3rd paper
T. Bhattacharjee and S. Umashankar	Mathematical modeling of an inverter was discussed in MATLAB/Simulink
A. A. Ansari and S. Shah	Mathematical modeling of an induction motor was discussed in MATLAB/Simulink

Literature Review

- Literature Review regarding SCADA system for Solar Water Pumping Systems

Paper Reviewed	Comments
M. Zamanlou	Discussed an Economical SCADA system for a solar water pumping system for Iranian conditions
M. Rijo	Discussed a SCADA system for monitoring of different parameters for a Portuguese Canal
J. G. Natividad	Discussed a SCADA system for a solar drying and water pumping system
F. J. Gimeno-Sales	Discussed a SCADA system for monitoring of a 2.4kW solar water pumping system
A. I. Abdelkerim	Discussed a LABVIEW based SCADA system for a solar powered irrigation system

Research Objectives

Research Objectives

- Design a solar water pumping system with a battery bank for a selected site in Pakistan using HOMER, which can be taken as a case study for future scenarios
- Perform dynamic analysis for the designed solar water pumping system in MATLAB/Simulink to validate the designed system in HOMER
- Design a solar water pumping system with a water tank for the same selected site using HOMER
- Comparison of the two designed solar water pumping systems and evaluate which one of the two designed systems is more feasible for Pakistani conditions
- Design an Emoncms based SCADA system that can store and reflect environmental, hydro and electrical parameters related to a solar water pumping system

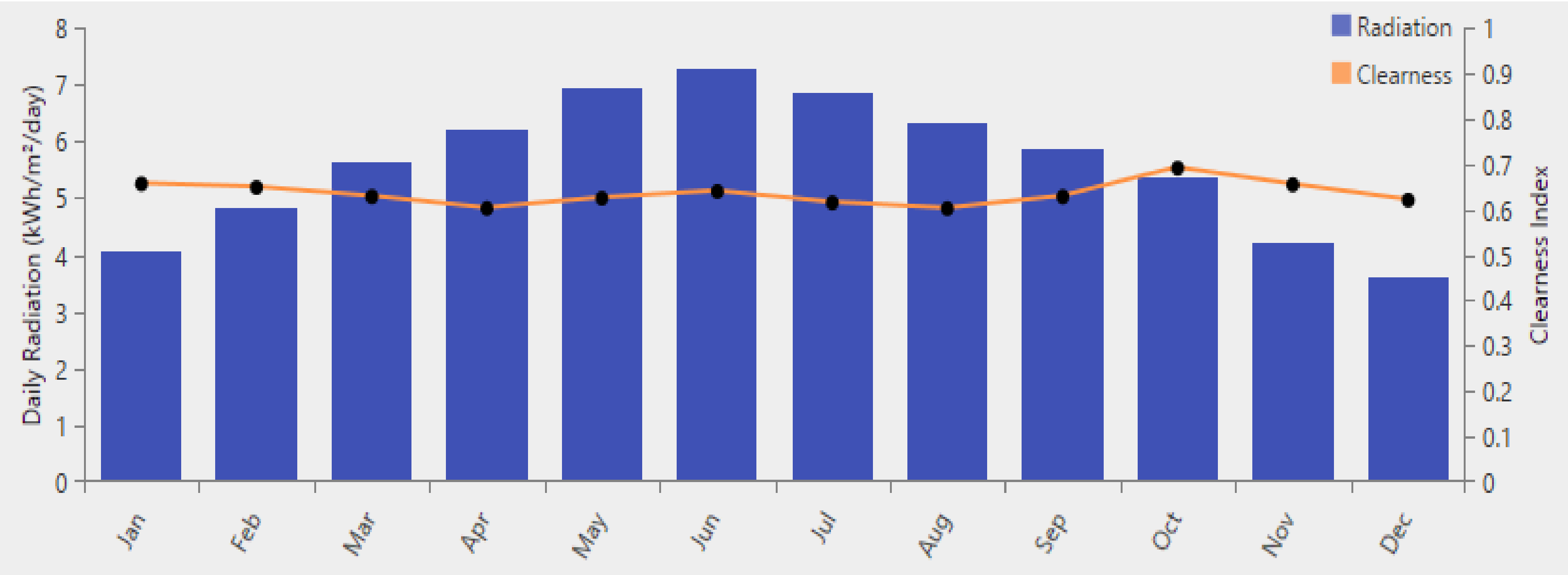
Design and Analysis of a Solar Water Pumping System in HOMER

Site Selection

- Mustafa Research Farms
- located at Wasti Jiuan Shah Tehsil Sadiqabad, Rahim Yar Khan, Pakistan
- It covers an area of around 239.6 acres of land
- The crop cultivated on this land is Rhodes Grass

Solar Insolation of the Selected Site

- Data for solar insolation was extracted from the National Renewable Energy Laboratory as its database is attached with HOMER
- The GHI (Global Horizontal Index) varies from 3.6 to 7.26 $kWh/m^2/day$
- The clearness index varies in the range of 0.601 to 0.69



Data obtained from the selected site

- Water level = 25ft = 7.62m
- Dynamic head = 35ft = 10.668m
- Water flow requirement = 2 cusec (cubic feet/sec) = 204m^3/hr = 898.2 gpm

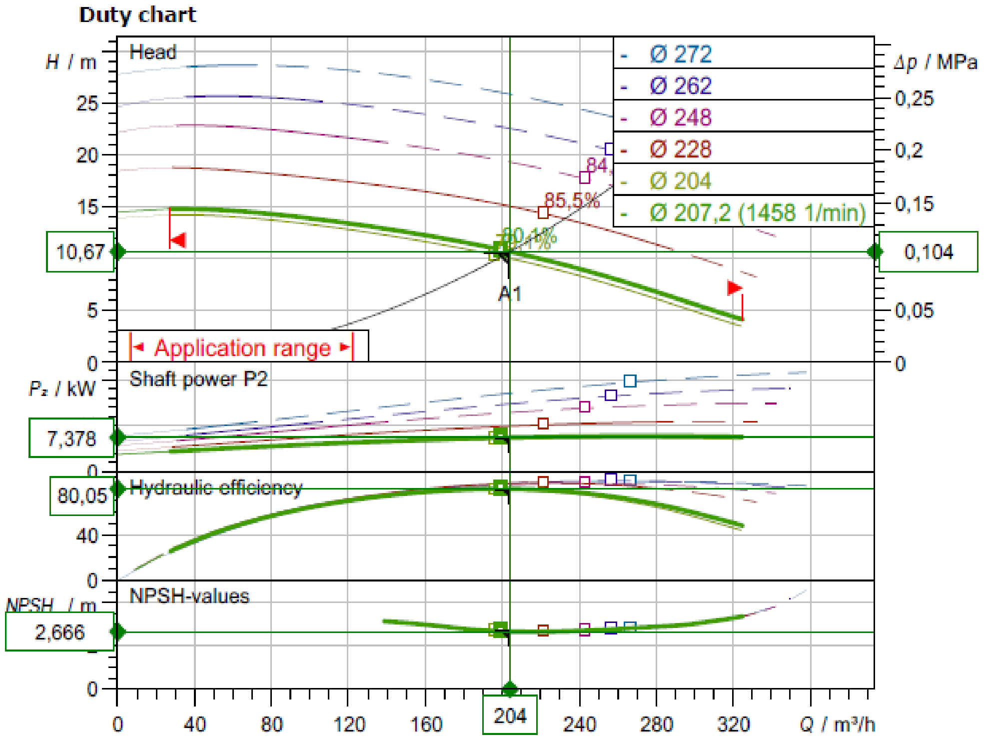
Motor Operation for the selected site

Months	Days of Full Operation (24 x 7)	Days of idle operation
January	First 7 days of the month	Next 24 days of the month
February	First 10 days of the month	Next 18 days of the month
March	First 11 days of the month	Next 20 days of the month
April	First 14 days of the month	Next 16 days of the month
May	First 17 days of the month	Next 14 days of the month
June	First 20 days of the month	Next 10 days of the month
July	First 22 days of the month	Next 9 days of the month
August	First 24 days of the month	Next 7 days of the month
September	First 18 days of the month	Next 12 days of the month
October	First 14 days of the month	Next 17 days of the month
November	First 10 days of the month	Next 20 days of the month
December	First 0 days of the month	Next 31 days of the month

Load Selection based on site Data

- The brand selected for the water pump/motor is Wilo.
- It has an online tool which was used to evaluate the pump size
- The required data (flow rate and total dynamic head of the motor) was incorporated in the online tool
- The motor rating came out to be 11kW, which is equivalent to 15hp
- Selected pump was Atmos GIGA-N 125/200-11/4

Selection Criteria for Pump



Pump curves in accordance with ISO 9906: 2012 3B

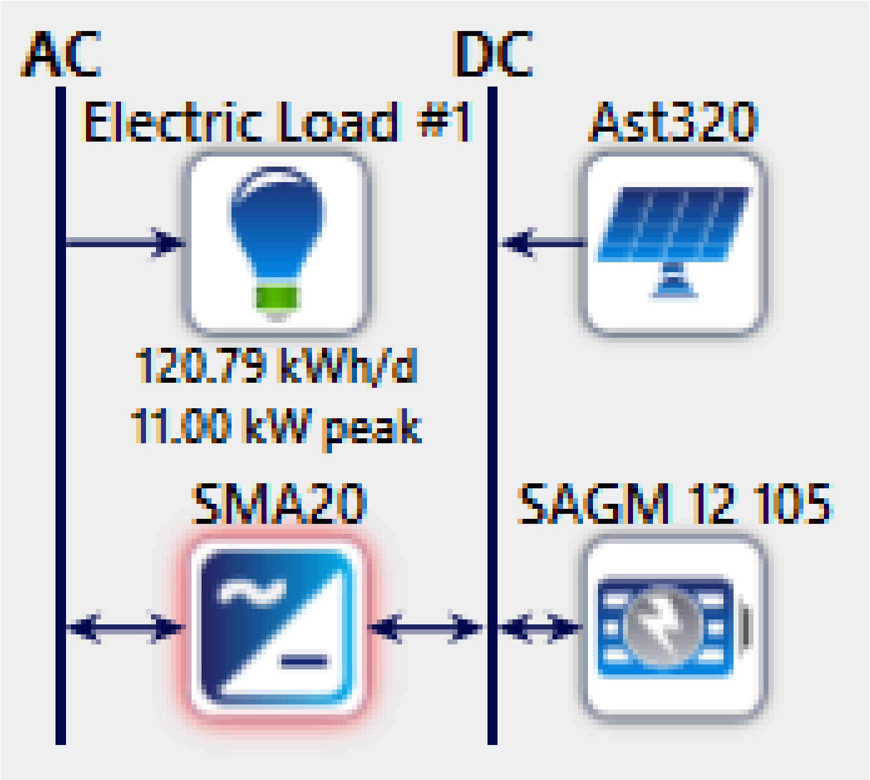
Requested data	
Flow	204,00 m³/h
Head	10,67 m
Media	Water 100 %
Fluid temperature	20,00 °C
Density	998,20 kg/m³
Kin. viscosity	1,00 mm²/s
Hydraulic data (Duty point)	
Flow	204,00 m³/h
Head	10,67 m
Shaft power P2	7,38 kW
Hydraulic efficiency	80,05 %
NPSH	2,67 m
Impeller size	207,2
Product data	
Glanded standard pump	
Atmos GIGA-N 125/250-11/4	
Max. operating pressure	1,6 MPa
Fluid temperature	-20 °C … +140 °C
Max. ambient temperature	40 °C
Minimum efficiency index (MEI)	≥ 0,4
Motordata per Motor/Pump	
Motor efficiency level	IE3
Mains connection	3~ 400 V / 50 Hz
Permitted voltage tolerance	±10 %
Max. speed	1470 1/min
Rated power P2	11,00 kW
Rated current	20,90 A
Power factor	0,77

Selected Pump details

Motor data
Mains connection: 3~400V/50 Hz
Voltage tolerance: ±10 %
Motor efficiency class: IE3
Rated power: 11 kW
Rated speed: 1470 1/min
Rated current: 20,9 A
Power factor: 0,77
Motor efficiency: 91,1 %
Motor efficiency: 91,8 %
Motor efficiency: 91,6 %
Protection class: IP55
Insulation class: F

Installation dimensions
Pipe connection on the suction side: DN 150 , PN16
Pipe connection on the pressure side: DN 125, PN16

Schematic of the Proposed Solar Water Pumping system in HOMER



Simulation Result for Sizing of Proposed Solar Water Pumping System in HOMER

- The PV panel network (Astronergy ASM6612P-320 solar panels) → 73.8kW
- The battery-bank based on Trojan SAGM 12 105 → 450
- The inverter requirement → 16.7kW ; SMA Sunny Tripower 20000TL-30

Simulation Result for Sizing of Proposed Solar Water Pumping System in HOMER

Simulation Results

System Architecture: SMA America STP20000TL-US-10 (480V) (16.7 kW)
Astronergy Solarmodule320ASM6612P 320 (73.8 kW) HOMER Cycle Charging
Trojan SAGM 12 105 (15.0 strings)

Total NPC:	$273,570.00
Levelized COE:	$0.4800
Operating Cost:	$5,692.37

SMA America STP20000TL-US-10 (480V) Emissions
Cost Summary Cash Flow Compare Economics Electrical Renewable Penetration Trojan SAGM 12 105 Astronergy Solarmodule320ASM6612P 320

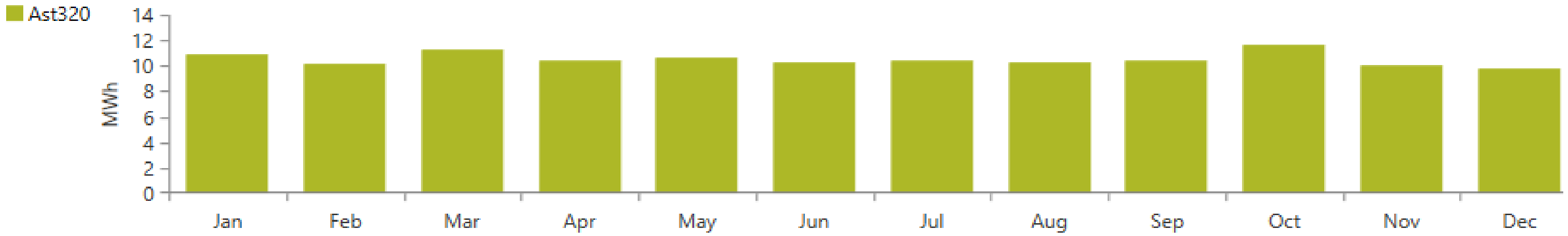
Production	kWh/yr
Astronergy Solarmodule320ASM6612P 320	126,095
Total	126,095

Consumption	kWh/yr	%
AC Primary Load	44,087	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	44,087	100

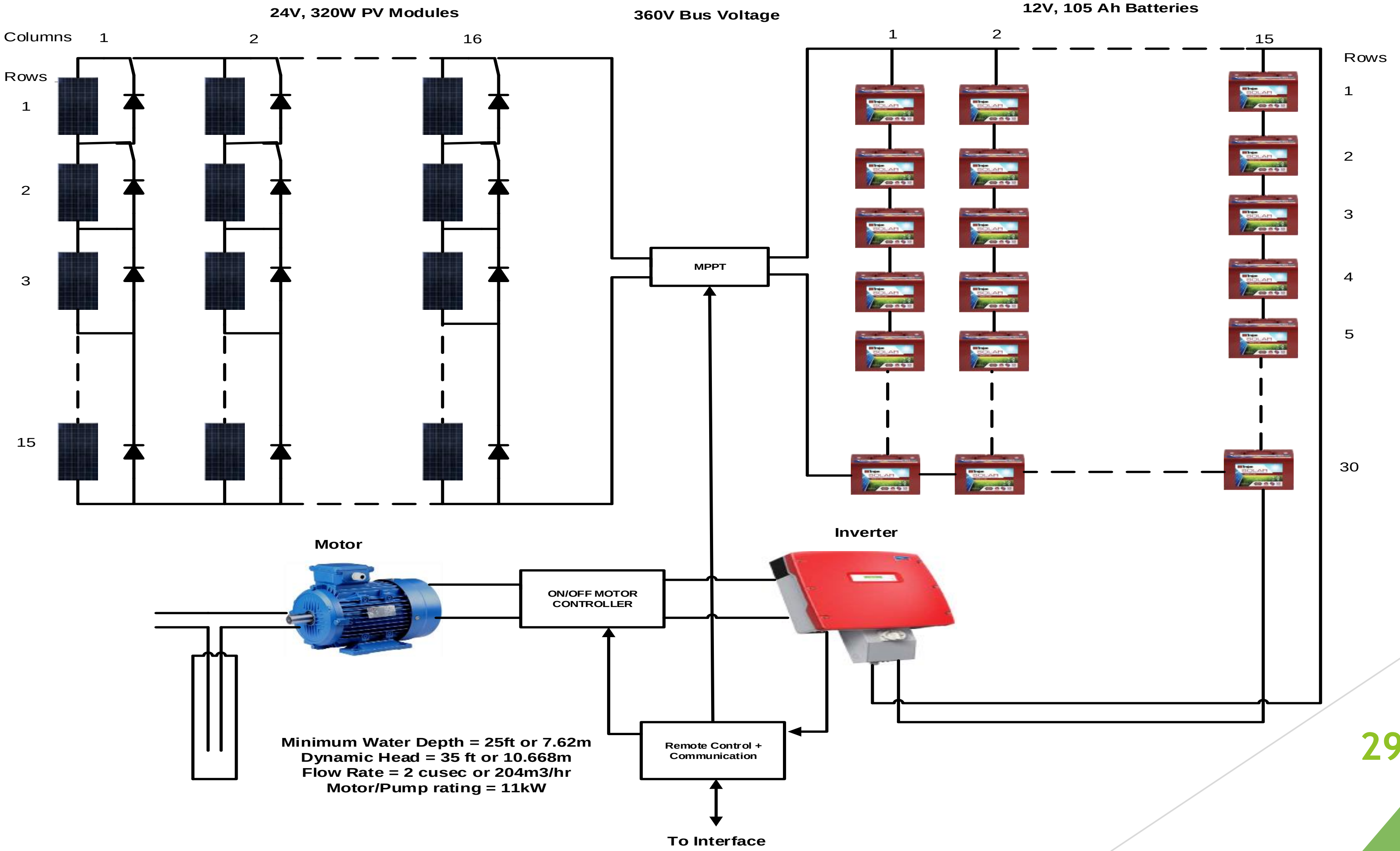
Quantity	kWh/yr	%
Excess Electricity	76,495	60.7
Unmet Electric Load	1.27	0.00290
Capacity Shortage	42.6	0.0966

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	614	%

Monthly Electric Production



Overall proposed solar water pumping system with a battery bank



Cash Summary for Proposed Solar Water Pumping System in HOMER

- Total net present cost of the overall system → $273,570
- Levelized cost of energy → $0.48
- Operating cost → $5,692.37 per year

Cash Summary for Proposed Solar Water Pumping System in HOMER

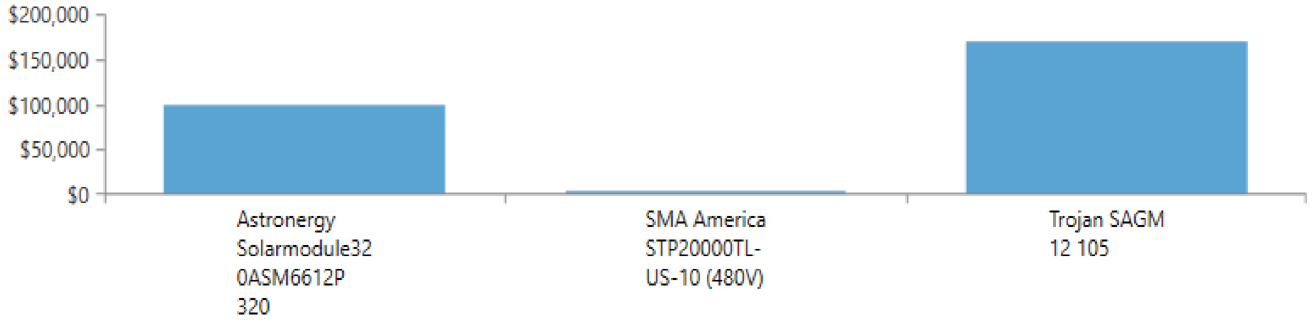
System Architecture:	SMA America STP20000TL-US-10 (480V) (16.7 kW)	Total NPC:	$273,570.00
Astronergy Solarmodule320ASM6612P 320 (73.8 kW)	HOMER Cycle Charging	Levelized COE:	$0.4800
Trojan SAGM 12 105 (15.0 strings)		Operating Cost:	$5,692.37

SMA America STP20000TL-US-10 (480V) Emissions

Cost Summary Cash Flow Compare Economics Electrical Renewable Penetration Trojan SAGM 12 105 Astronergy Solarmodule320ASM6612P 320

Cost Type
- Net Present
- Annualized

Categorize
- By Component
- By Cost Type

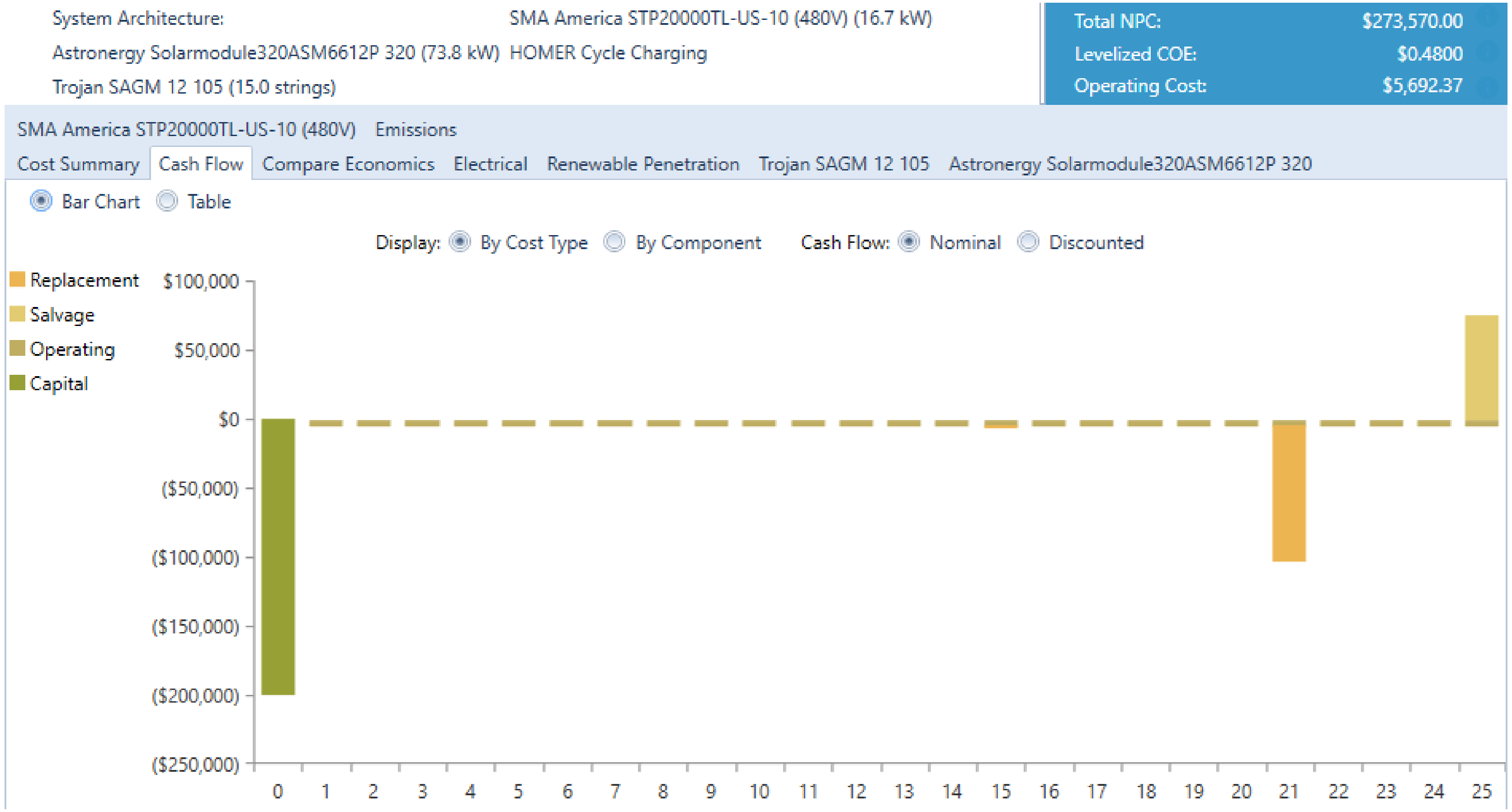


Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Astronergy Solarmodule320ASM6612P 320	$39,713.02	$0.00	$59,663.29	$0.00	$0.00	$99,376.31
SMA America STP20000TL-US-10 (480V)	$2,768.84	$1,174.75	$0.00	$0.00	($221.10)	$3,722.49
Trojan SAGM 12 105	$157,500.00	$31,119.79	$0.00	$0.00	($18,148.56)	$170,471.23
System	$199,981.86	$32,294.53	$59,663.29	$0.00	($18,369.66)	$273,570.03

Cash Flow for Proposed Solar Water Pumping System in HOMER

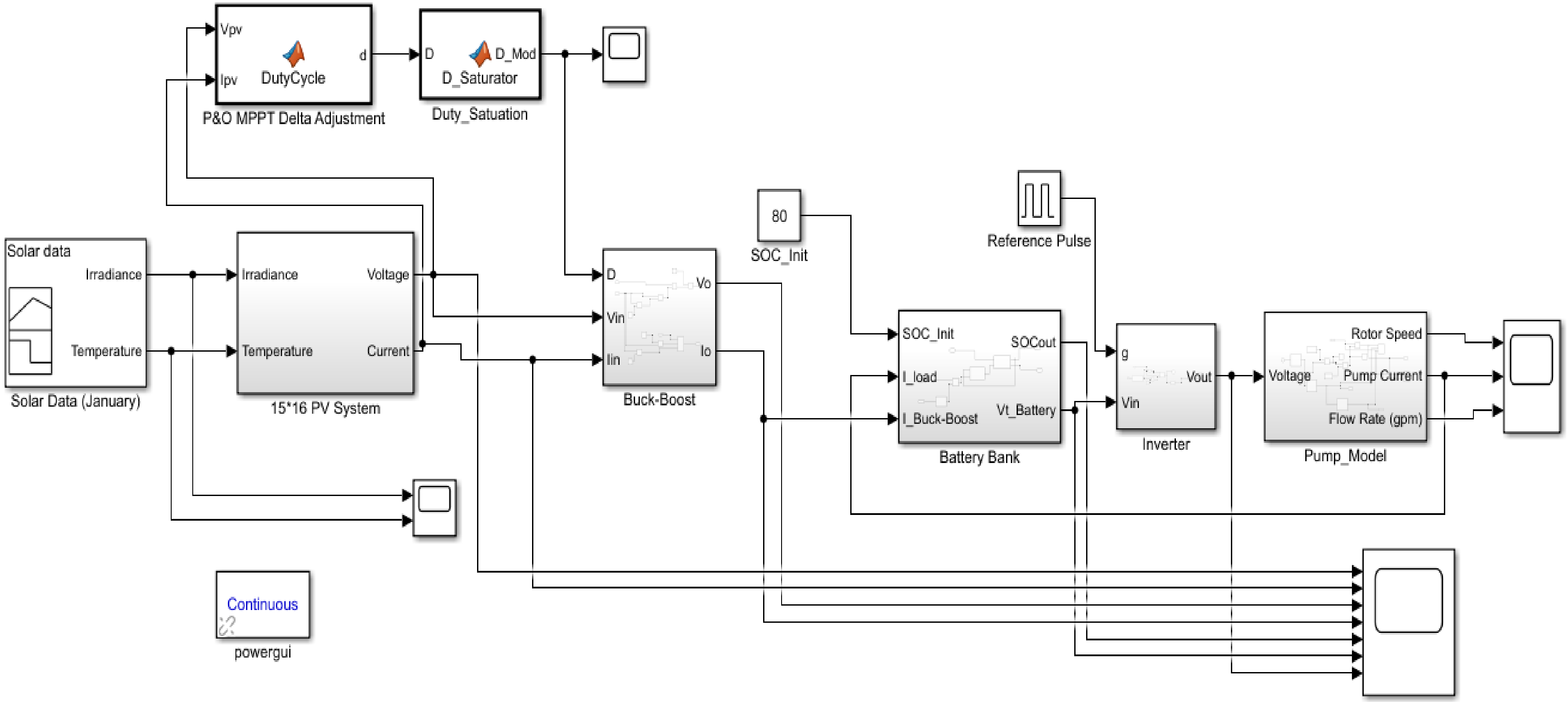
- As per cash flow over the life cycle of 25 years for the proposed system
- The initial investment → $199,981.86
- Annual investment required → $4,615.22
- In the 21st year investment → $99,000
- At the end of 25th year; salvage value → $76,681.52

Cash Flow for Proposed Solar Water Pumping System in HOMER



Dynamic Modeling of Designed Solar Water Pumping System in MATLAB/Simulink

Dynamic Model in MATLAB/Simulink

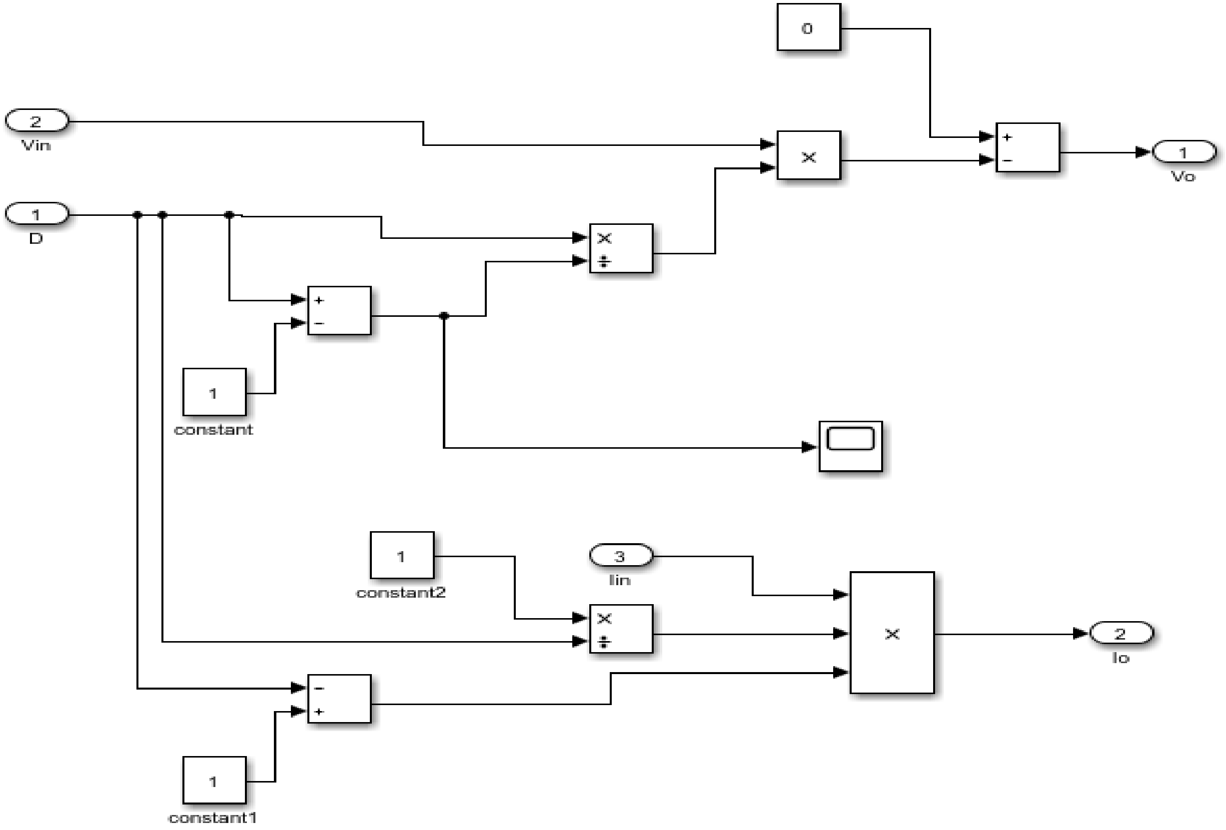


PV Panel Modeling

- Equations Modeled in Subsystem
- $I_{ph} = \left[I_{sc} + k_i.(T - 298).\frac{G}{1000}\right]$ (1)
- $I_0 = I_{rs}.\left[\frac{T}{T_n}\right]^3.exp\left[\frac{q.E_{g0}.\left(\frac{1}{T_n}-\frac{1}{T}\right)}{n.k}\right]$ (2)
- $I_{rs} = \frac{I_{sc}}{e^{\left(\frac{q.V_{OC}}{n.N_S.k.T}\right)}-1}$ (3)
- $I_{sh} = \left[\frac{V+I.R_S}{R_{sh}}\right]$ (4)
- $I = I_{ph} - I_0\left[exp\left[\frac{q.(V+1.R_S)}{n.k.N_S.T}\right] - 1\right] - I_{sh}$ (5)

Buck-Boost Modeling

- $V_o = -\frac{V_i k}{1-k}$ (6)
- $I_i = \frac{I_o k}{1-k}$ (7)



Battery Bank Modeling

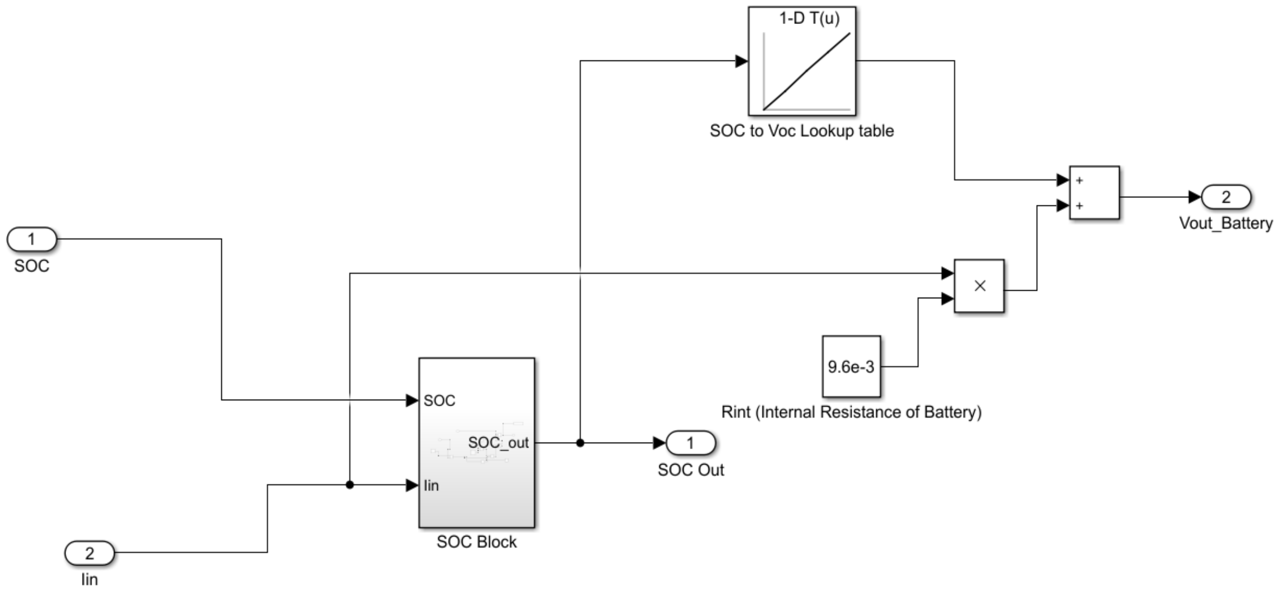
- State of Charge for Battery Bank
- $SOC(t) = SOC_{(t=o)} - \frac{1}{3600}\int_{0}^{t(Sec)} I_B\, dt$ (SOC Equation for Discharging)
- $SOC(t) = SOC_{(t=o)} + \frac{1}{3600}\int_{0}^{t(Sec)} I_B\, dt$ (SOC Equation for Charging)

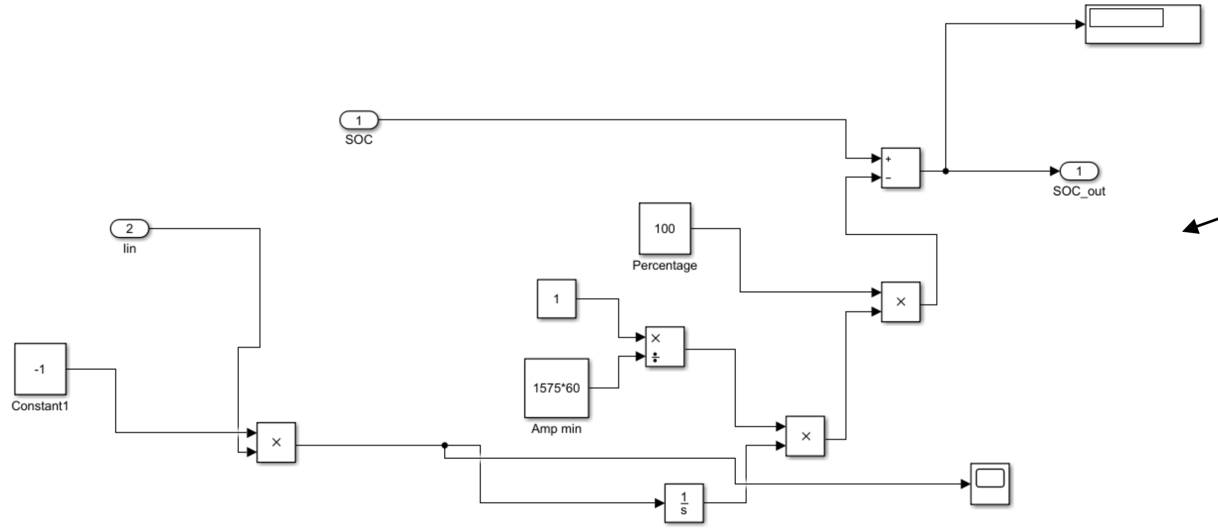
Maximum Charge Current (A) 20% of C20	21x15=315A
Absorption Voltage (2.40 V/cell)	14.4x30=432V
Float Voltage (2.25 V/cell)	13.5x30=405V

SOC %	Cell V	V open Circuit	
100	2.14	12.84x30	385.2
75	2.09	12.54x30	376.2
50	2.04	12.24x30	367.2
25	1.99	11.94x30	358.2
0	1.94	11.64x30	349.2

INTERNAL RESISTANCE (mΩ)	4.8x30/15=9.6 m ohm
CAPACITY A AMP-HOURS (AH)	105x15=1575

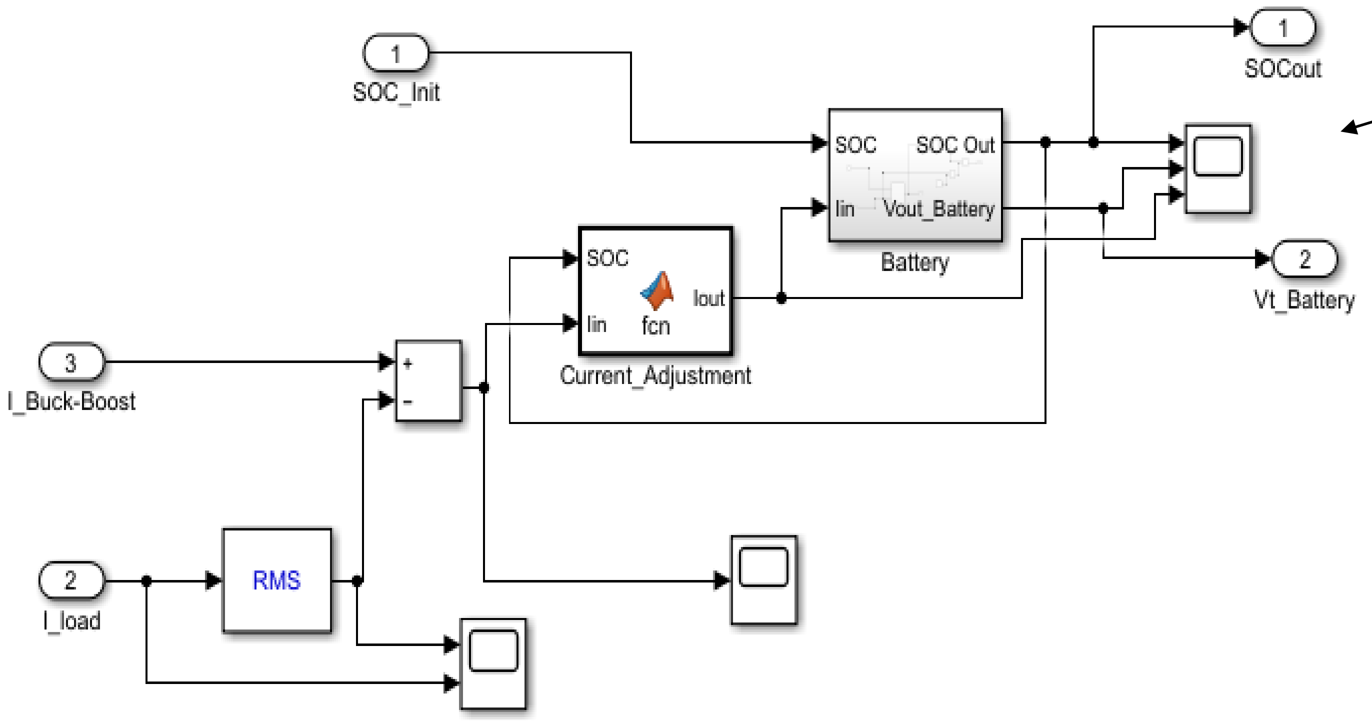
Battery Bank Modeling





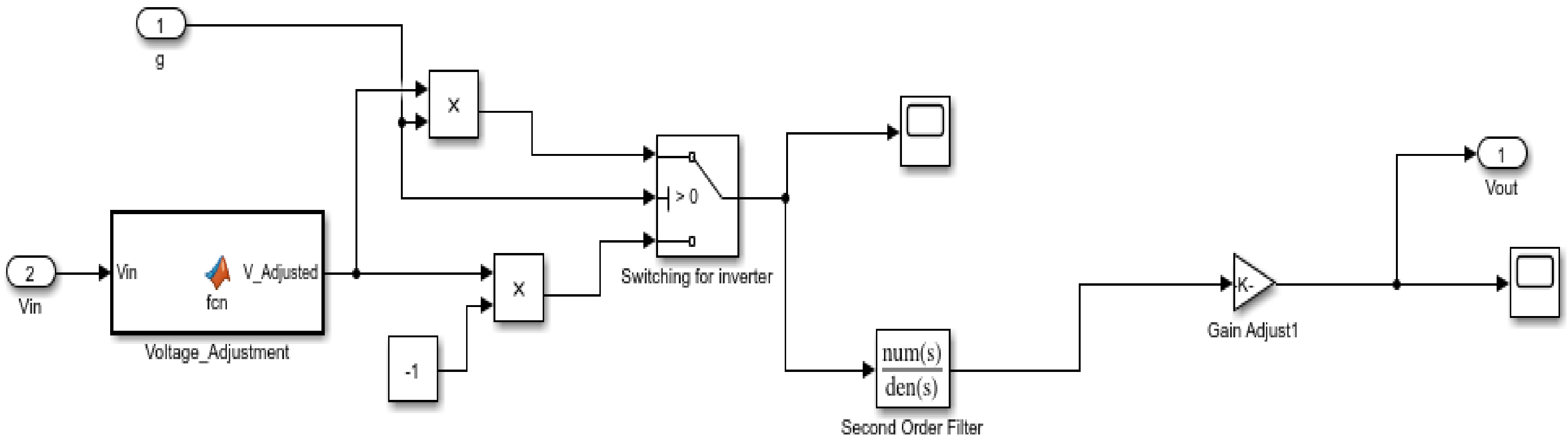
SOC Block

Battery Bank Modeling



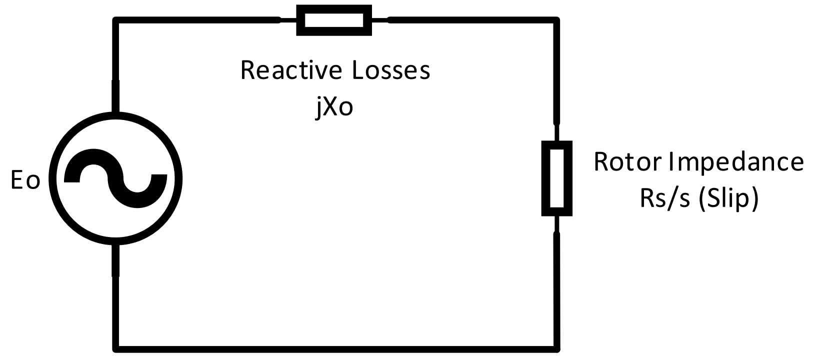
Input Scheme to Battery Block

Inverter Modeling



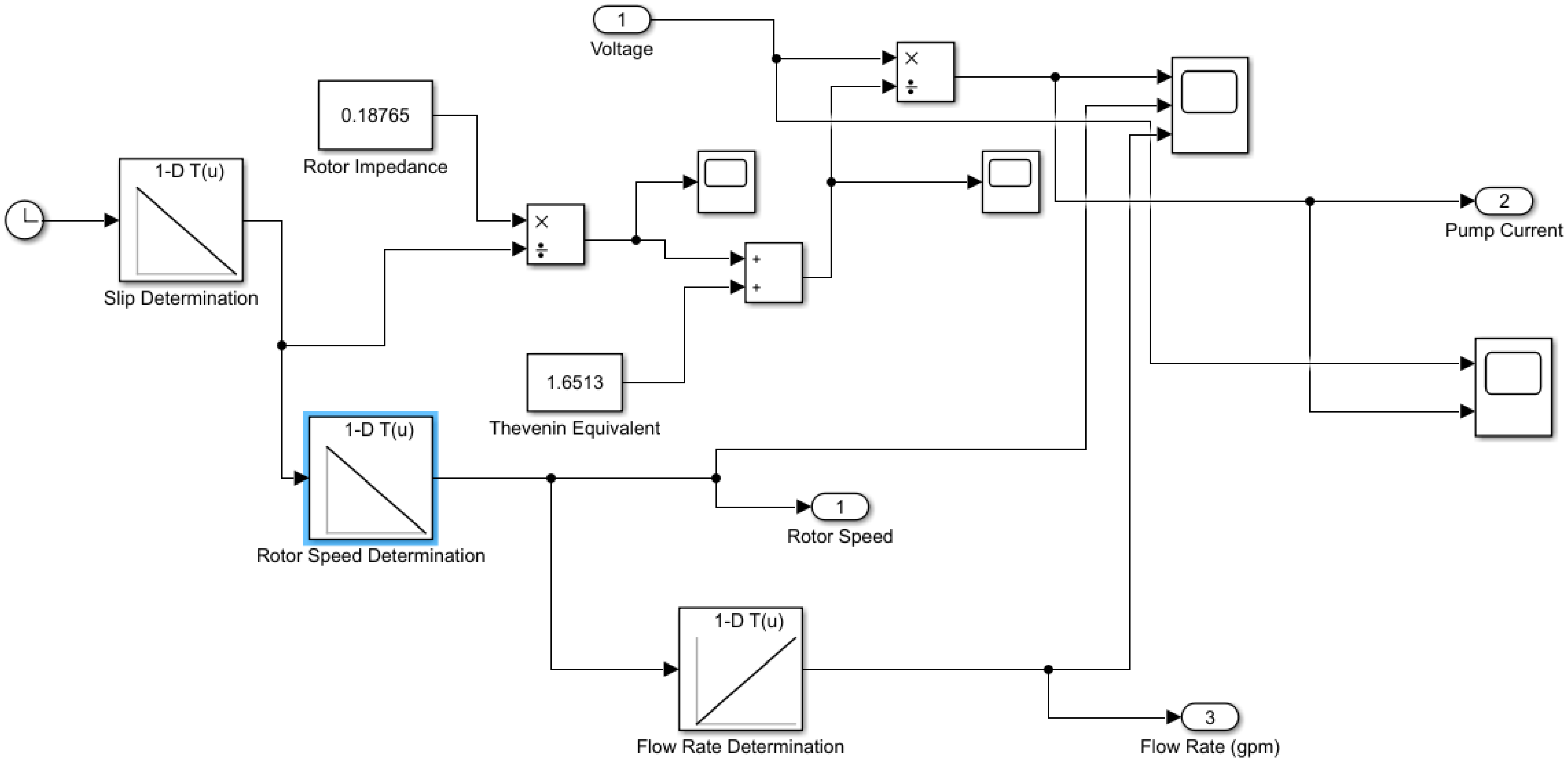
Motor/Pump Modeling

- For modeling equivalent diagram for Induction motor was used



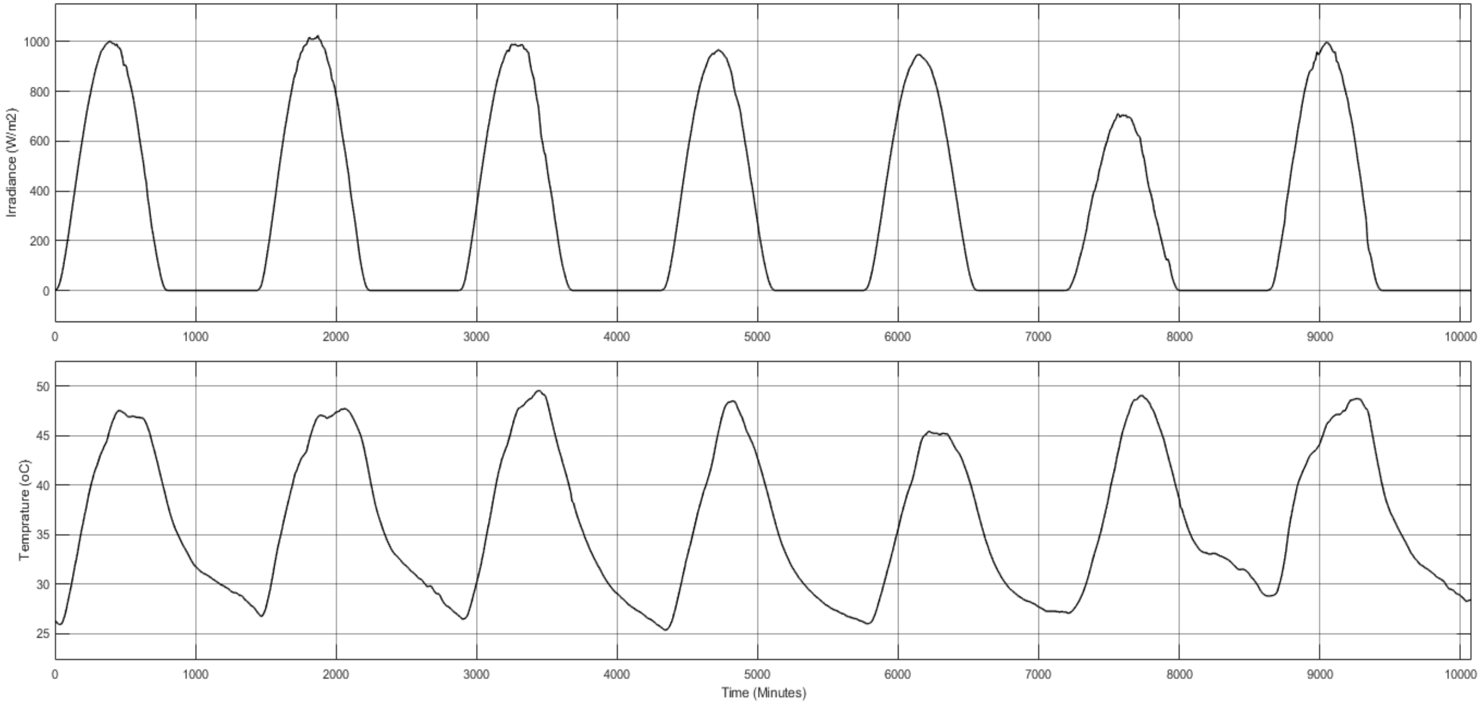
- $E_0 = I(jX_o + \frac{R_s}{s})$
- Design Assumptions
- Inrush current was taken to be 6 times rated peak current (29.6 x 6 = 177.6)
- The inrush current settles after 25 seconds
- After computations
- Rs → 0.18976
- jX_o →1.6513

Motor/Pump Modeling in MATLAB/Simulink

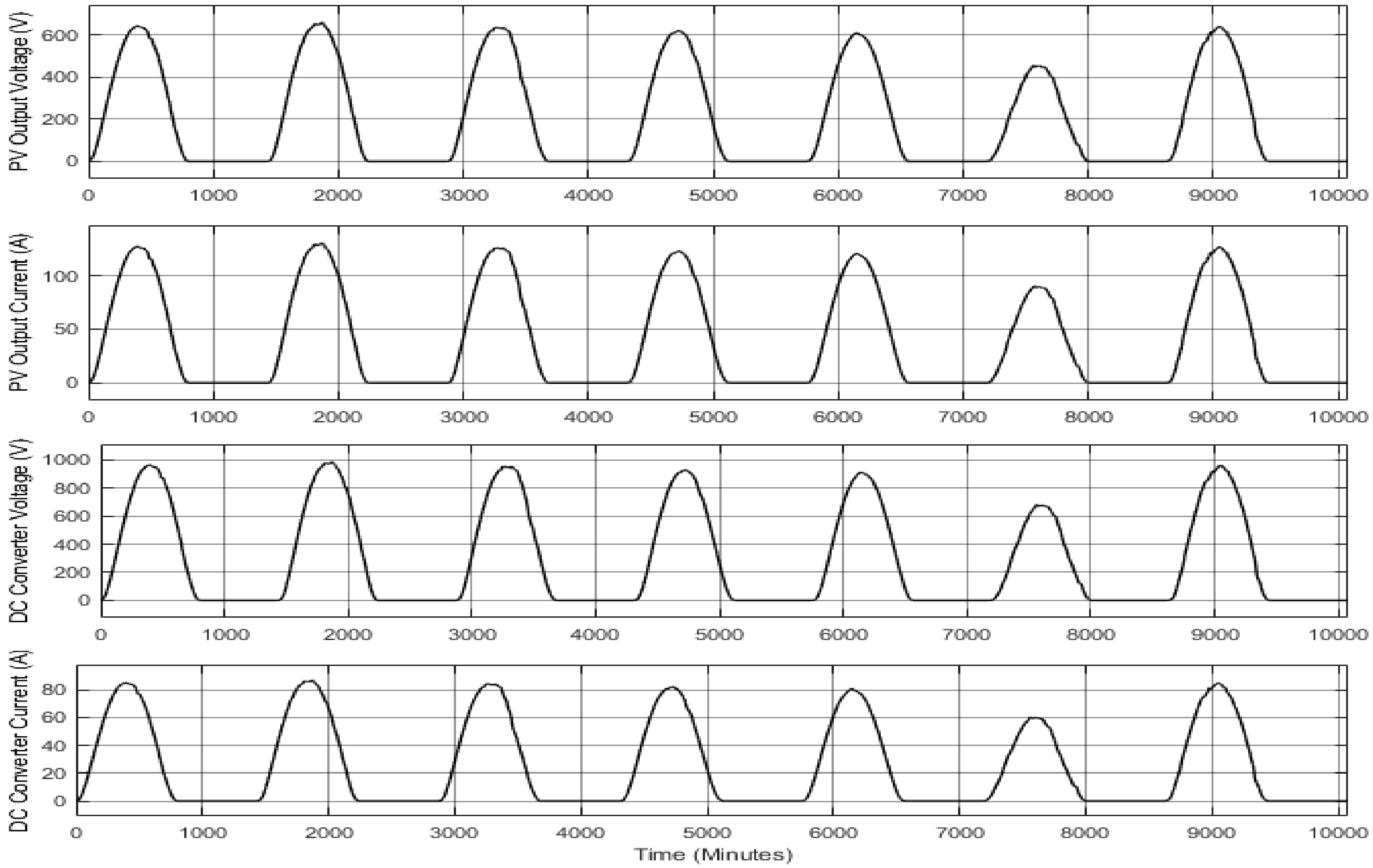


Input Solar Irradiation and Temperature

- Data for 1st 7 days of April was taken
- The irradiance varied from 0 to 1021 W/m^2
- The temperature varied from 25 to 49.5^oC



Simulation Results of the proposed designed system



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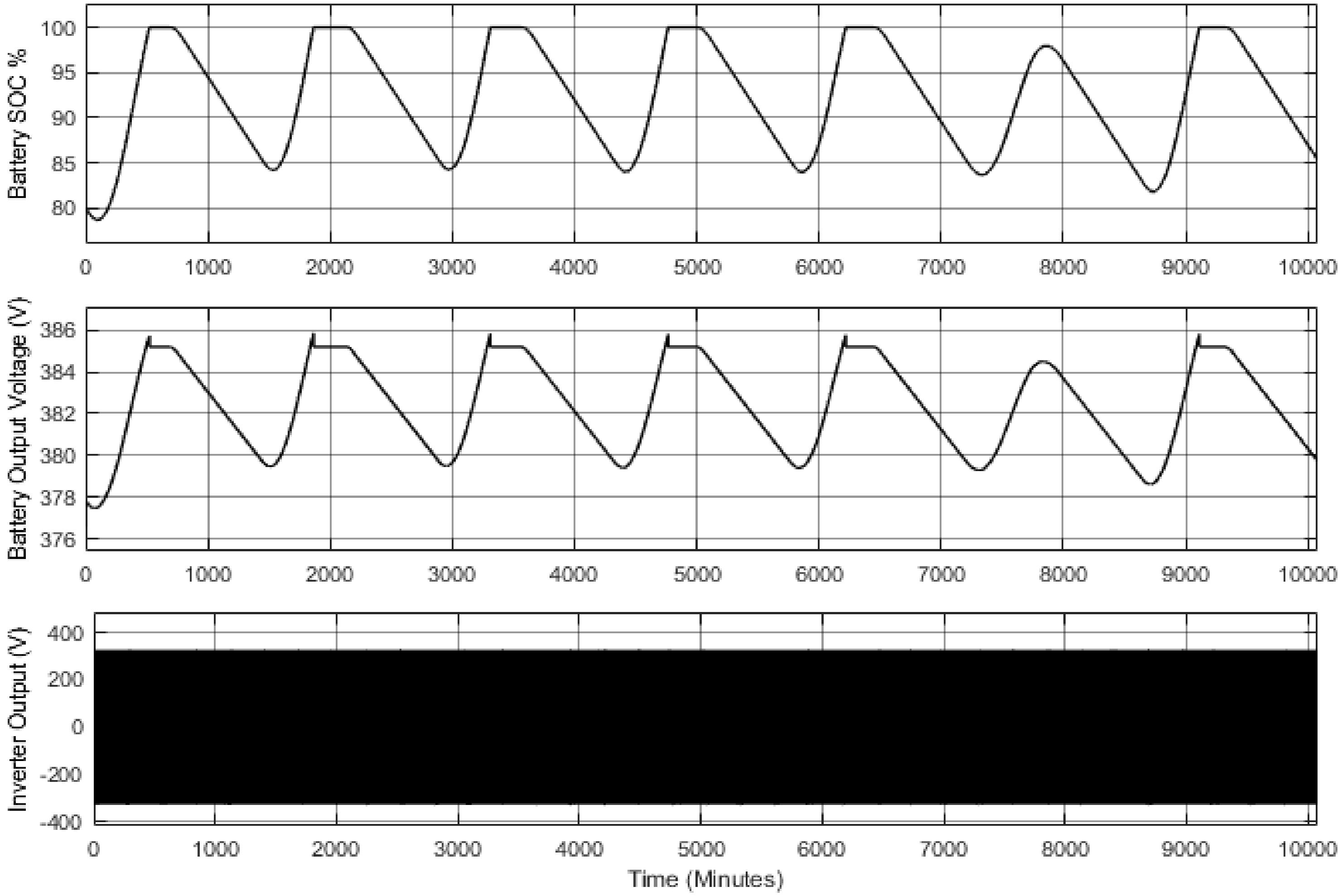

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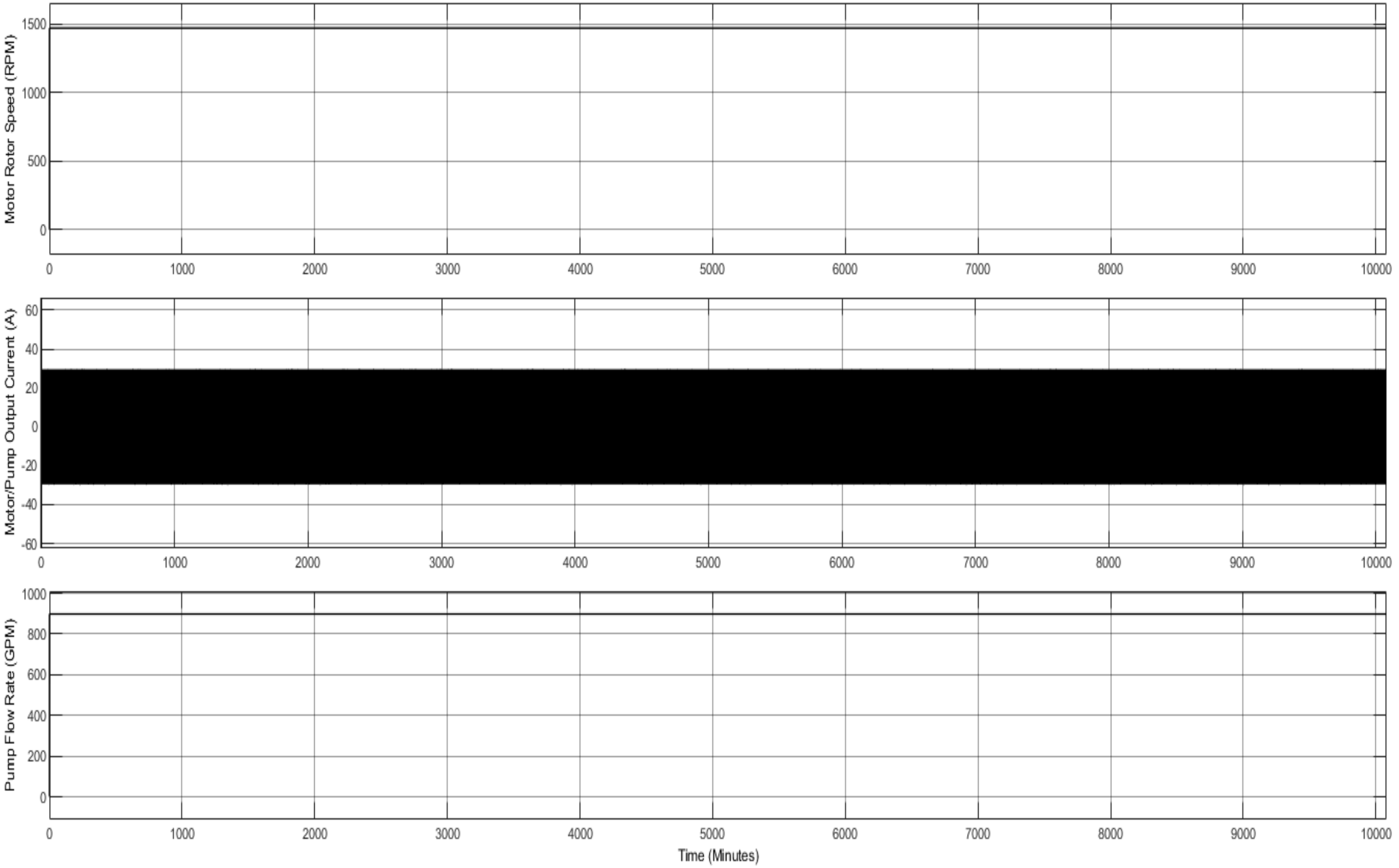


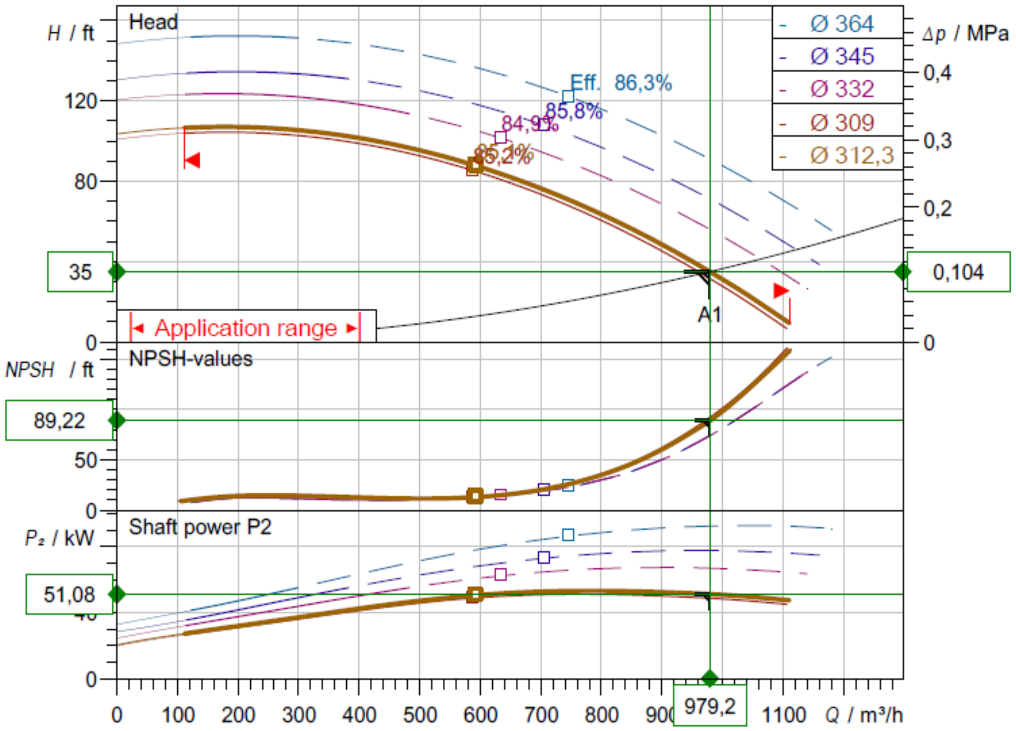
Design and Analysis of a Solar Water Pumping System with Water Tank in HOMER

Load Determination

- Flow rate for 1 day → $204 m^3/hr \times 24 = 4896 m^3$
- Considering motor running for 5 hours
- $4896/5 = 979.2\ m^3/hr$
- Using Wilo Online tool
- the size of the pump → 55kW
- Selected Pump came as CronoNorm-NLG 250/360-55/4

Selection Criteria for Pump

Duty chart



Requested data

Flow	979,20 m³/h
Head	35,00 ft
Media	Water 100 %
Fluid temperature	20,00 °C
Density	998,20 kg/m³
Kin. viscosity	1,00 mm²/s

Hydraulic data (Duty point)

Flow	979,20 m³/h
Head	35,00 ft
Shaft power P2	51,08 kW
Hydraulic efficiency	55,33 %
NPSH	89,22 ft
Impeller size	312,3

Product data

Glanded standard pump

NLG 250/360-55/4

Max. operating pressure	1,6 MPa
Fluid temperature	-20 °C ... +120 °C
Max. ambient temperature	40 °C
Minimum efficiency index (MEI)	≥ 0,4

Motordata per Motor/Pump

Motor efficiency level	IE3
Mains connection	3~ 400 V / 50 Hz
Permitted voltage tolerance	±10 %
Max. speed	1480 1/min
Rated power P2	55,00 kW
Rated current	98,60 A
Power factor	0,85

Data of Selected Pump

Operating data
Fluid media: Water 100 %
Fluid temperature: 20,00 °C
Fluid concentration: 100,00 %
Requested flow: 979,20 m^3/h
Requested head: 35,00 ft
Min. fluid temperature: -20 °C
Max. fluid temperature: 120 °C
Maximum operating pressure: 16 bar
Max. ambient temperature: 40 °C
Minimum efficiency index (MEI): ≥ 0,4

Motor data
Mains connection: 3~400V/50 Hz
Voltage tolerance: ±10 %
Motor efficiency class: IE3
Rated power: 55 kW
Rated speed: 1480 1/min
Rated current: 98,6 A
Power factor: 0,85
Motor efficiency: 0,0 %
Motor efficiency: 0,0 %
Motor efficiency: 0,0 %
Protection class:
Insulation class: F

Installation dimensions
Pipe connection on the suction side: DN 300, PN16
Pipe connection on the pressure side: DN 250, PN16

Sizing of the Proposed System using HOMER

- As the motor is running for 5 hours
- So a 55 x 5 = 275kWh is the storage capacity required

DEFERRABLE LOAD

Name: Water Pump

Remove

Scaled Annual Average (kWh/d): 123.48

Storage Capacity (kWh): 275.00

Peak Load (kW): 55.00

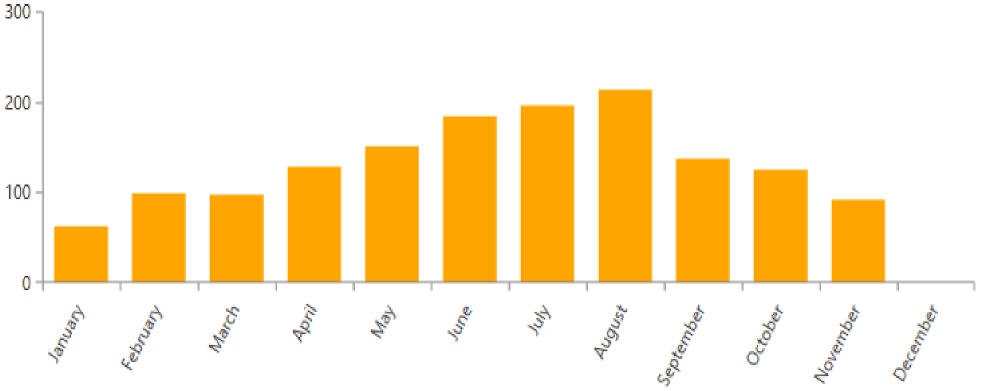
Minimum load ratio (%): 0.00

Electrical Bus: AC DC

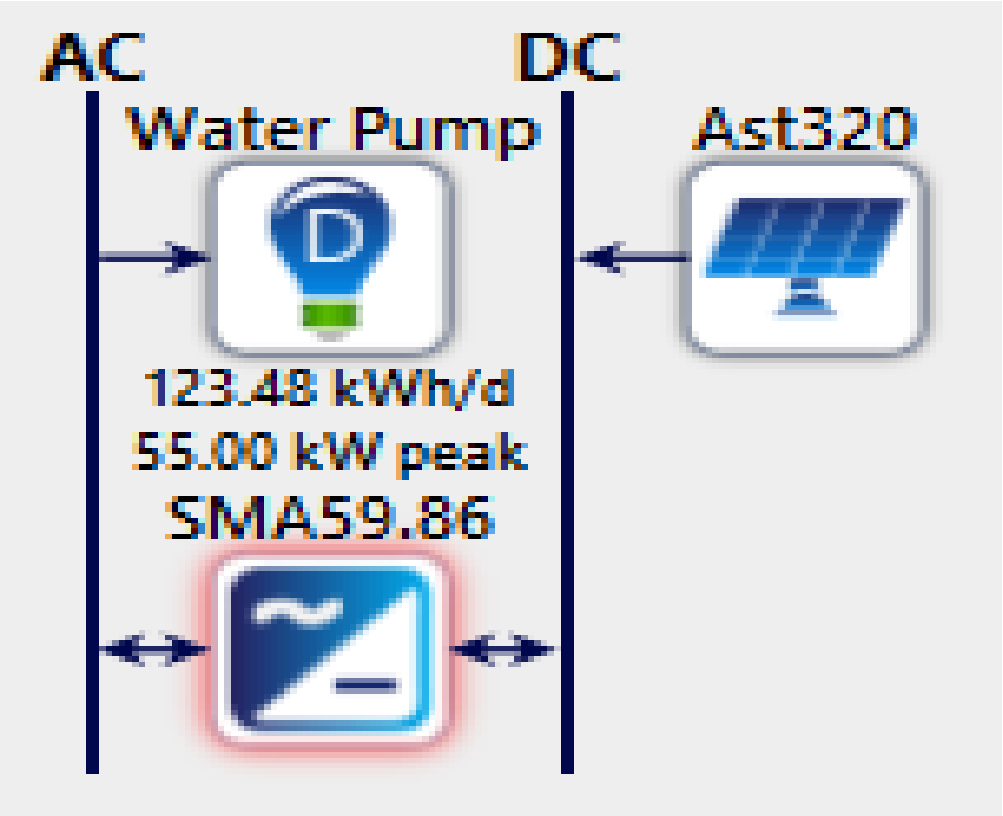
Enter Monthly Averages

Month	Average Load (kWh/d)
January	62.097
February	98.214
March	97.581
April	128.333
May	150.806
June	183.333
July	195.161
August	212.903
September	137.500
October	124.194
November	91.666
December	0.000

Annual Average (kWh/d): 0.00



Schematic for Proposed PV based water pumping system with Water Tank



Simulation Result for Sizing of Proposed Solar Water Pumping System with Water Tank in HOMER

- The PV Panel network requirement →72.3kW
- The Inverter requirement → 59.9kW
- Fulfilled by a 60kW SMA American STP60-US-10

Simulation Result for Sizing of Proposed Solar Water Pumping System with Water Tank in HOMER

Simulation Results

System Architecture: HOMER Cycle Charging

Astronergy Solarmodule320ASM6612P 320 (72.3 kW)

SMA America STP 60-US-10 (400 VAC) (59.9 kW)

Total NPC:	$103,858.30
Levelized COE:	$0.1783
Operating Cost:	$4,649.93

Emissions

Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Astronergy Solarmodule320ASM6612P 320 | SMA America STP 60-US-10 (400 VAC)

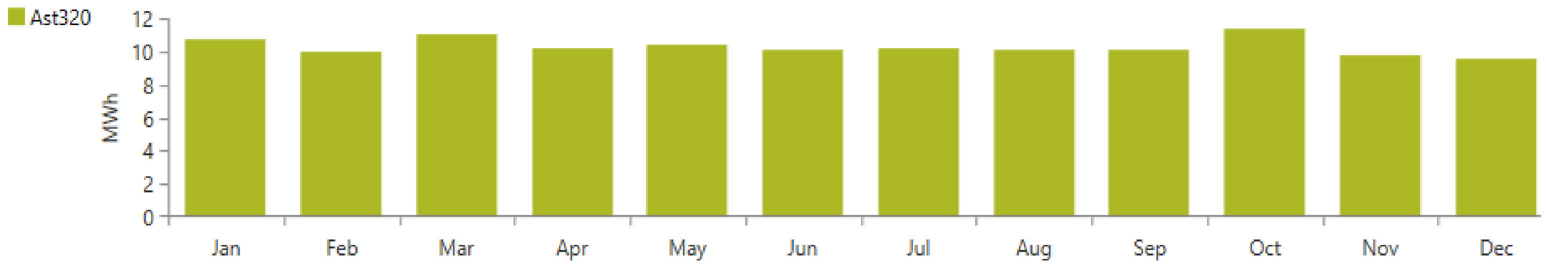
Production	kWh/yr
Astronergy Solarmodule320ASM6612P 320	123,516
Total	123,516

Consumption	kWh/yr	%
AC Primary Load	0	0
DC Primary Load	0	0
Deferrable Load	45,056	100
Total	45,056	100

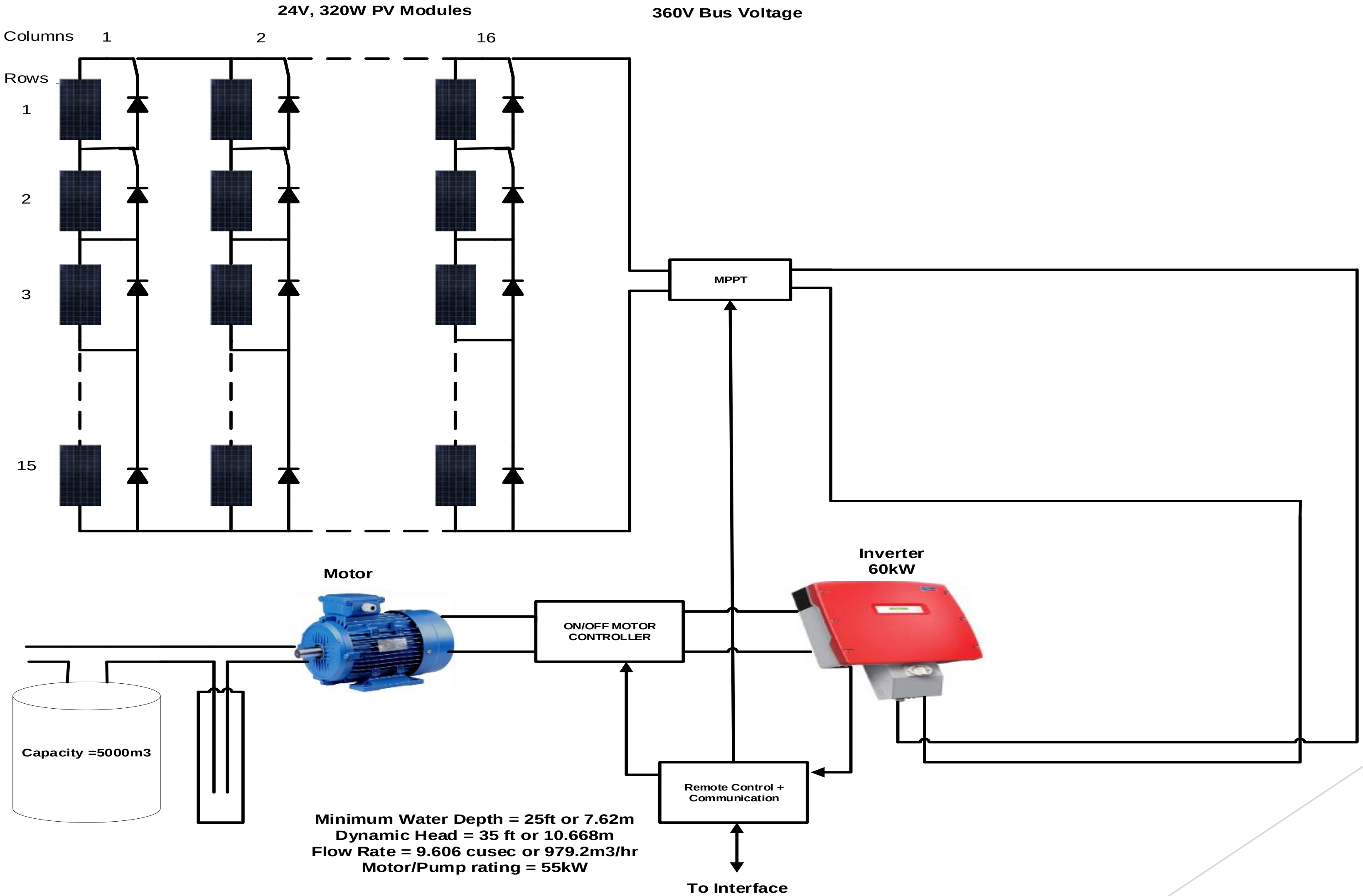
Quantity	kWh/yr	%
Excess Electricity	77,541	62.8
Unmet Electric Load	44.3	0.0982
Capacity Shortage	44.3	0.0982

Quantity	Value	Units
Renewable Fraction	100	%
Max. Renew. Penetration	2,573	%

Monthly Electric Production



Proposed solar water pumping system with water tank



Cash Summary for Proposed Solar Water Pumping System in HOMER

- Total net present cost of the overall system → $103,858.30
- Levelized cost of energy → $0.1783
- Operating cost → $4,649.93 per year

Cash Summary for Proposed Solar Water Pumping System in HOMER

System Architecture: HOMER Cycle Charging
Astronergy Solarmodule320ASM6612P 320 (72.3 kW)
SMA America STP 60-US-10 (400 VAC) (59.9 kW)

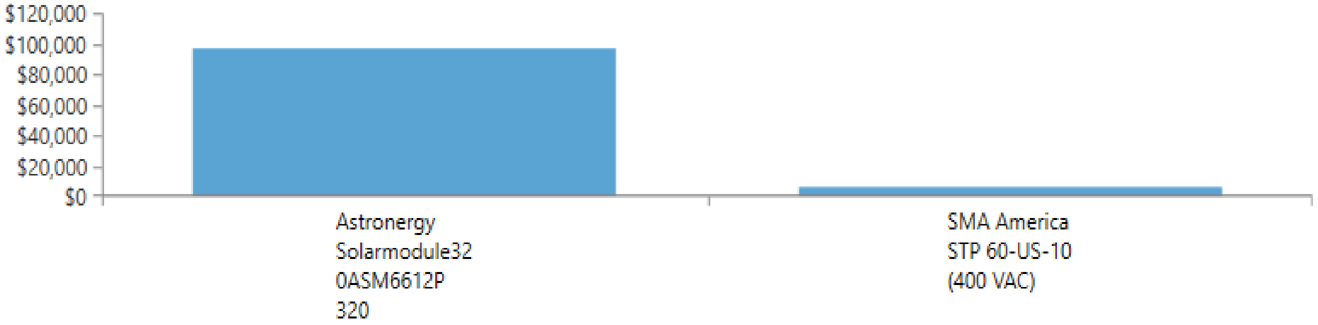
Total NPC:	$103,858.30
Levelized COE:	$0.1783
Operating Cost:	$4,649.93

Emissions

Cost Summary | Cash Flow | Compare Economics | Electrical | Renewable Penetration | Astronergy Solarmodule320ASM6612P 320 | SMA America STP 60-US-10 (400 VAC)

Cost Type
- Net Present
- Annualized

Categorize
- By Component
- By Cost Type

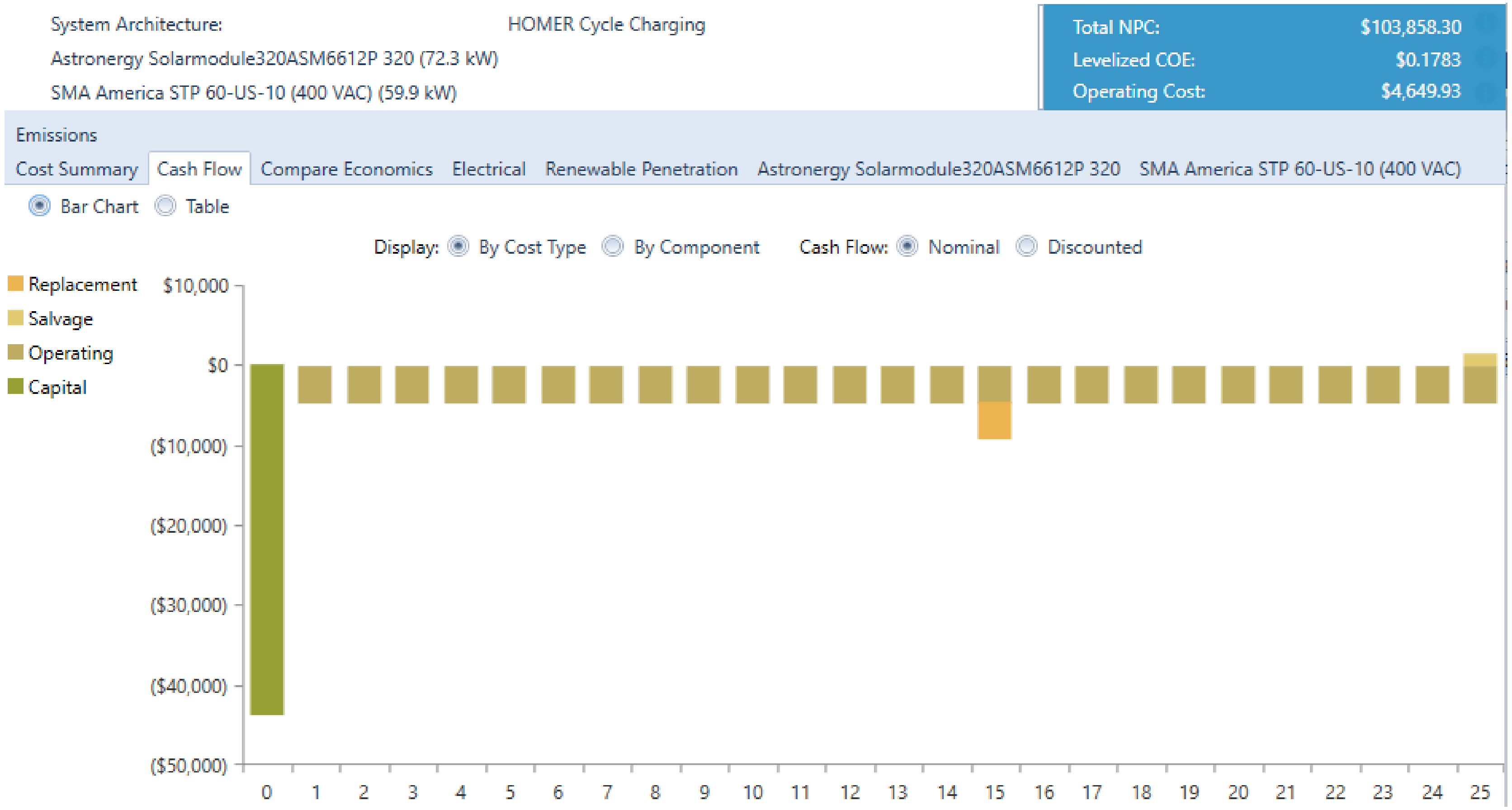


Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Astronergy Solarmodule320ASM6612P 320	$38,900.87	$0.00	$58,443.15	$0.00	$0.00	$97,344.01
SMA America STP 60-US-10 (400 VAC)	$4,845.41	$2,055.78	$0.00	$0.00	($386.92)	$6,514.27
System	$43,746.27	$2,055.78	$58,443.15	$0.00	($386.92)	$103,858.28

Cash Flow for Proposed Solar Water Pumping System in HOMER

- As per cash flow over the life cycle of 25 years for the proposed system
- The initial investment → $43,746.27
- Annual investment required → $4,520.83
- In the 15th year investment → $4,845.41
- At end of 25th year; salvage value → $1615.14

Cash Flow for Proposed Solar Water Pumping System in HOMER



Sizing of Water Tank

- As the total water discharge in one day was 4896m^3, so a tank of 5000m^3 was planned
- Considering, a cylindrical tank of 5000m^3 with a height of 2m
- The radius of the tank came as 28.21m

Costing of Water Tank

- The local rate for construction, including material, labor, digging and supervision lumped together, cost Rs300/ft^2
- Surface area = 2854.6m^2 = 30726.6587ft^2
- Overall price for tank is 30727 x 300 = Rs 92,181,00 = $54,540.88

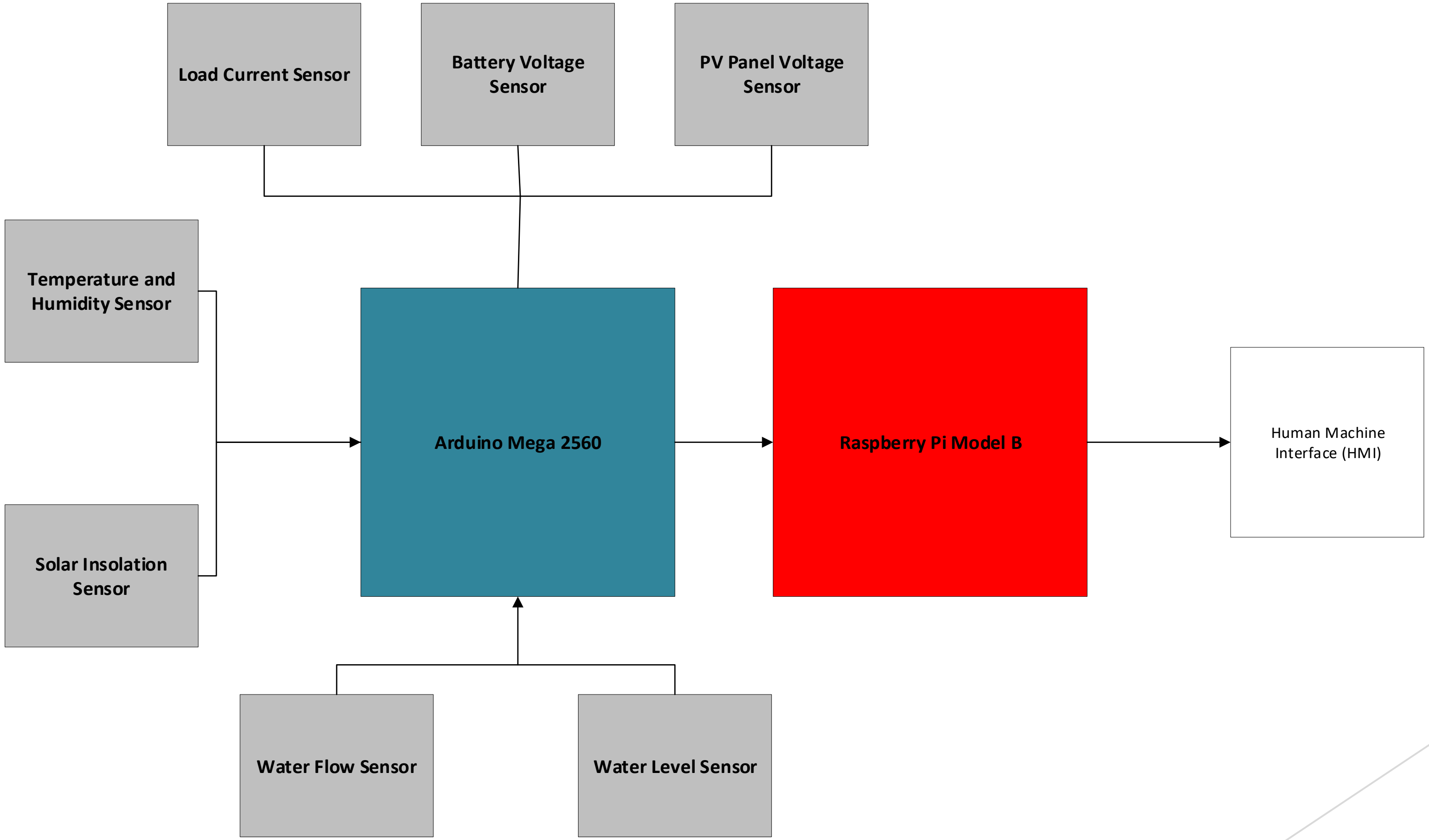
Comparison of Solar water pumping systems with battery bank and Water Tank

Proposed System with Battery Bank	Proposed System with Water Tank
Net Present Cost → $273,570	Net Present Cost → $158,399
Levelized cost of Energy → $0.48	Levelized cost of Energy → $0.1783
Operating costs → $5,692.37	Operating costs → $4,649.93
Initial Investment → $199,981.86	Initial Investment → $98,327.15

Solar Water Pumping System with Water Tank came out to be a more feasible solution for Pakistani Conditions

Supervisory Control and Data Acquisition (SCADA) for a Solar Water Pumping System

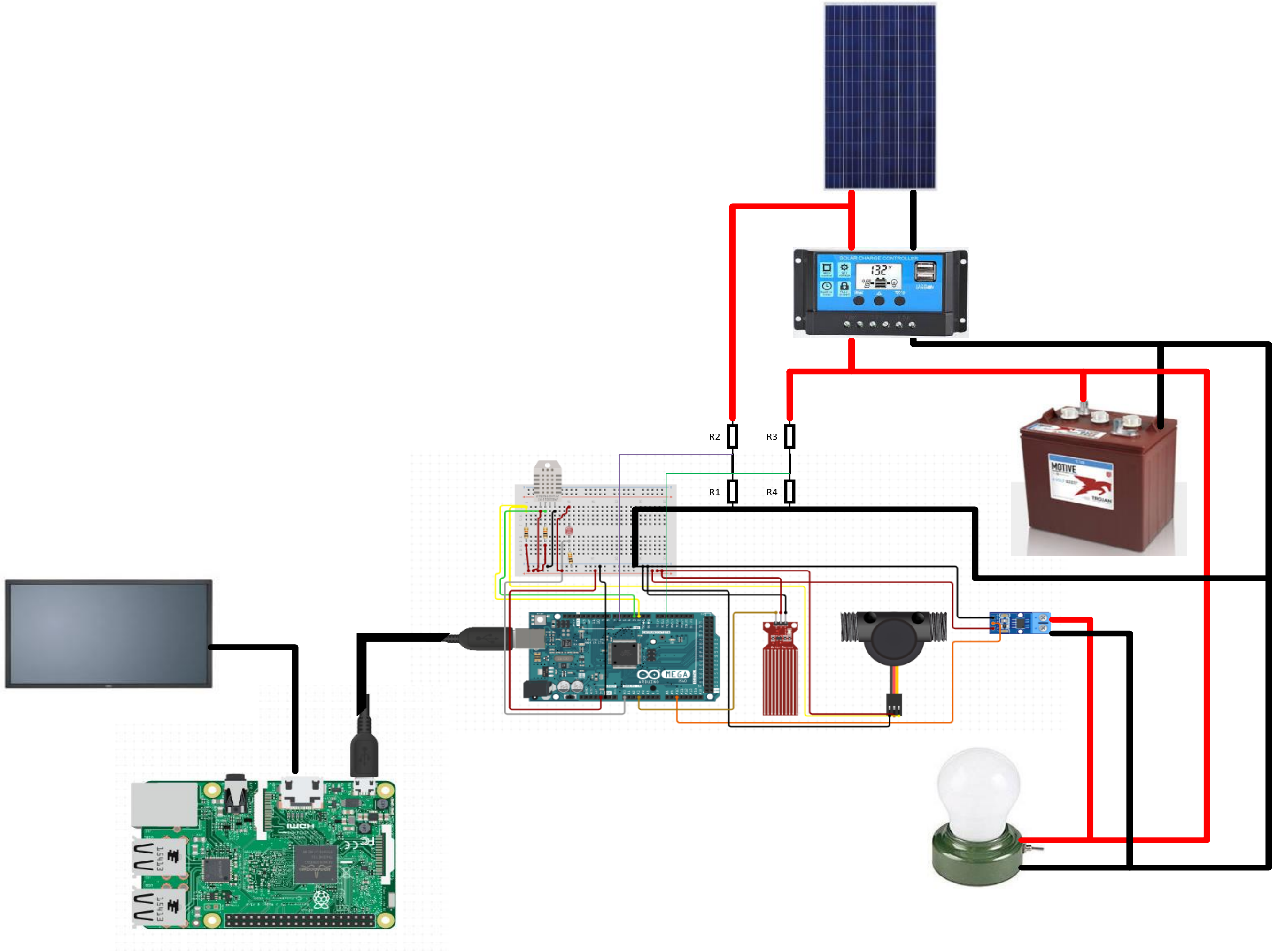
Emoncms SCADA based system for Solar Water Pumping System



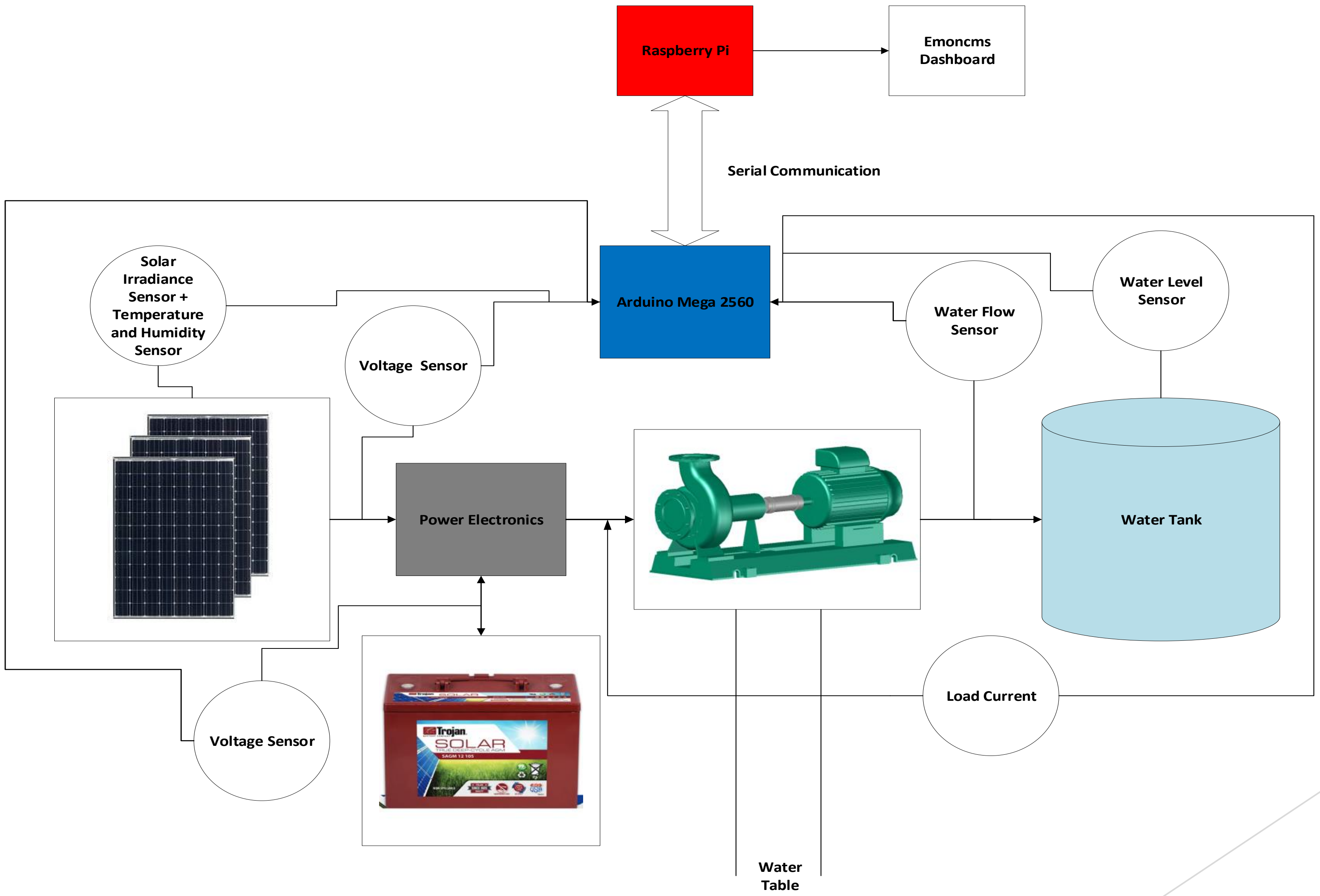
Component List for SCADA

Serial Number	Component Name	Use
1	Raspberry Pi Model 4 B	It has Emoncms installed, which serve as an HMI
2	Arduino Mega 2560	It acts as a hub for sensors, which takes the data from sensors and push it forward to Raspberry Pi
3	Current Sensor Module (ACS712)	Used to sense load current
4	Water flow Sensor (YFS-201)	Used to sense water flow in liters/minute
5	Water Level Sensor	Used to sense the water level in the tank
6	Temperature and Humidity Sensor (DHT-22)	Used to sense temperature and humidity of the surroundings
7	Photo-resistor	Used to sense solar irradiance of the surrounding
8	Set of Resistors used	These are used to set up potential dividers for voltage measurement of PV panel and battery

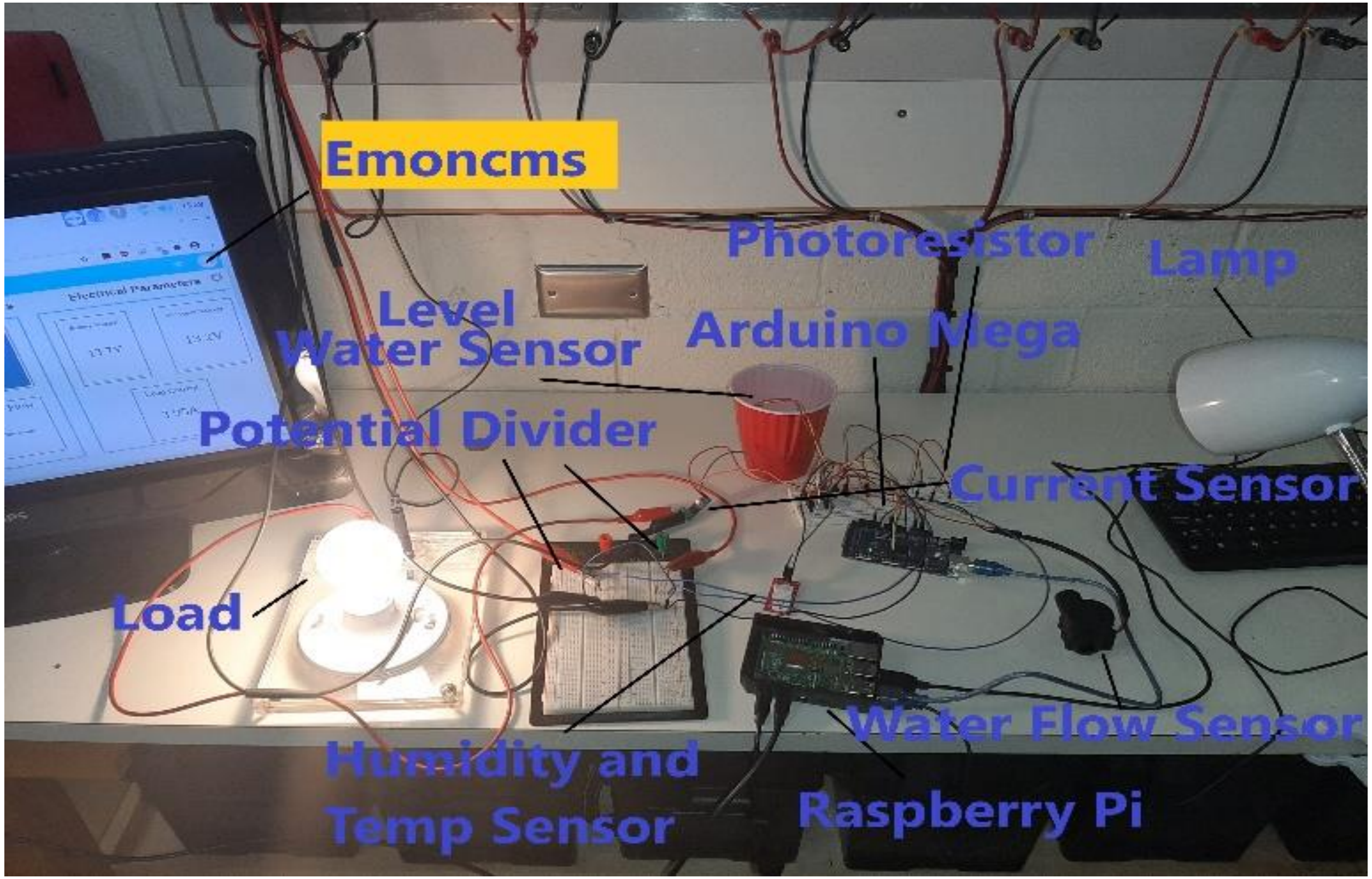
Circuit Diagram of Proposed SCADA System for Solar Water Pumping System



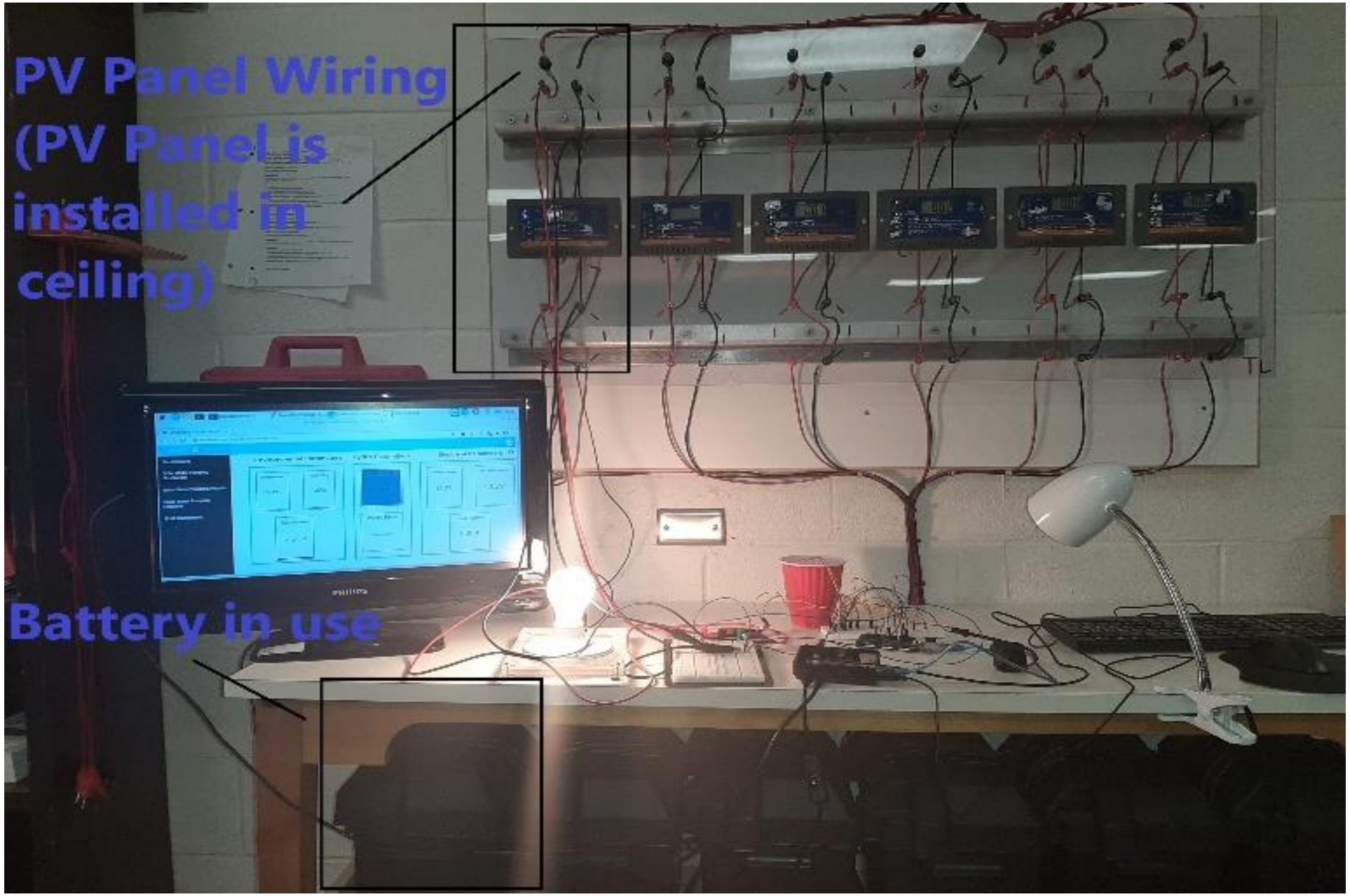
Proposed SCADA System



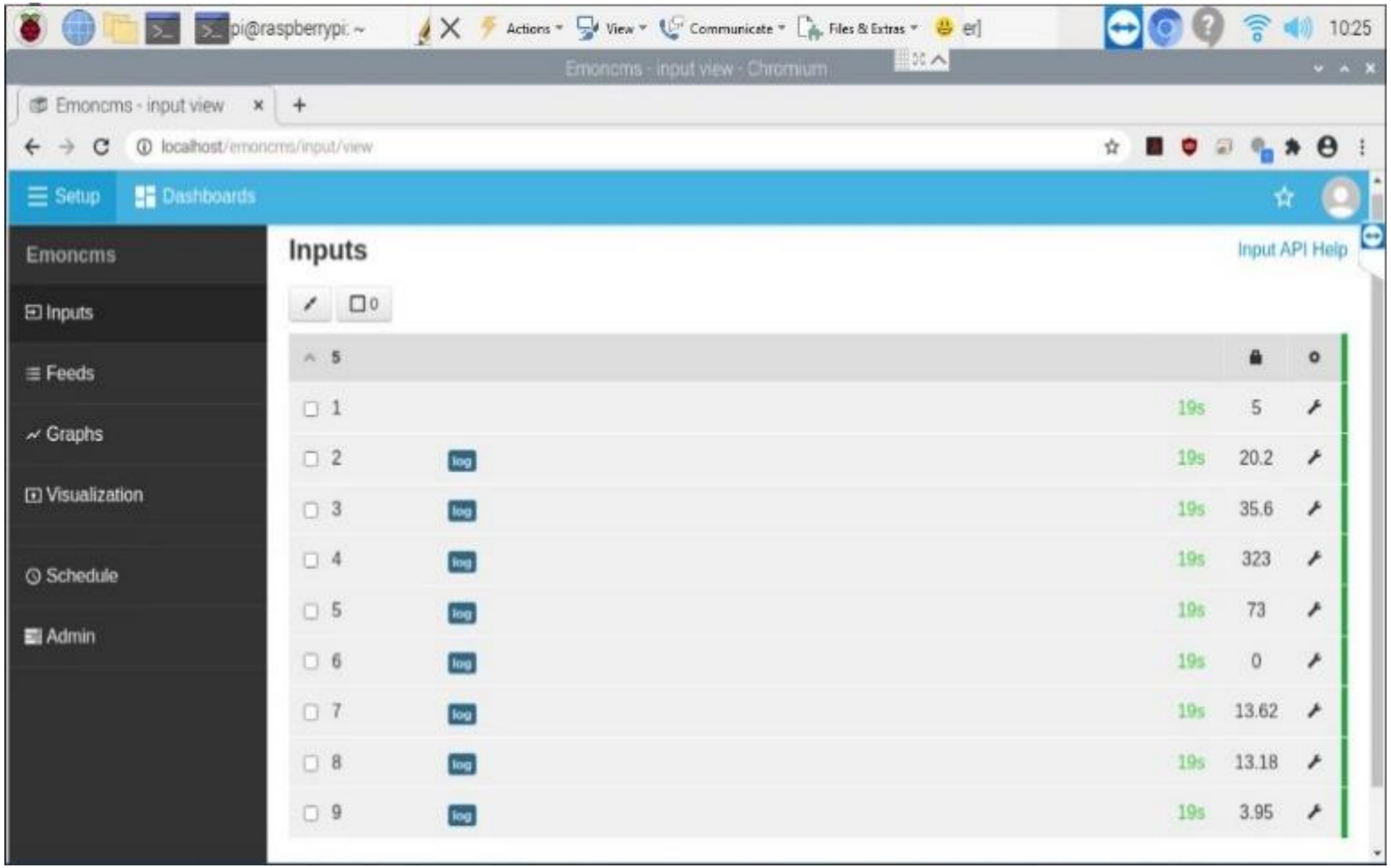
Prototype of Proposed SCADA system in Lab



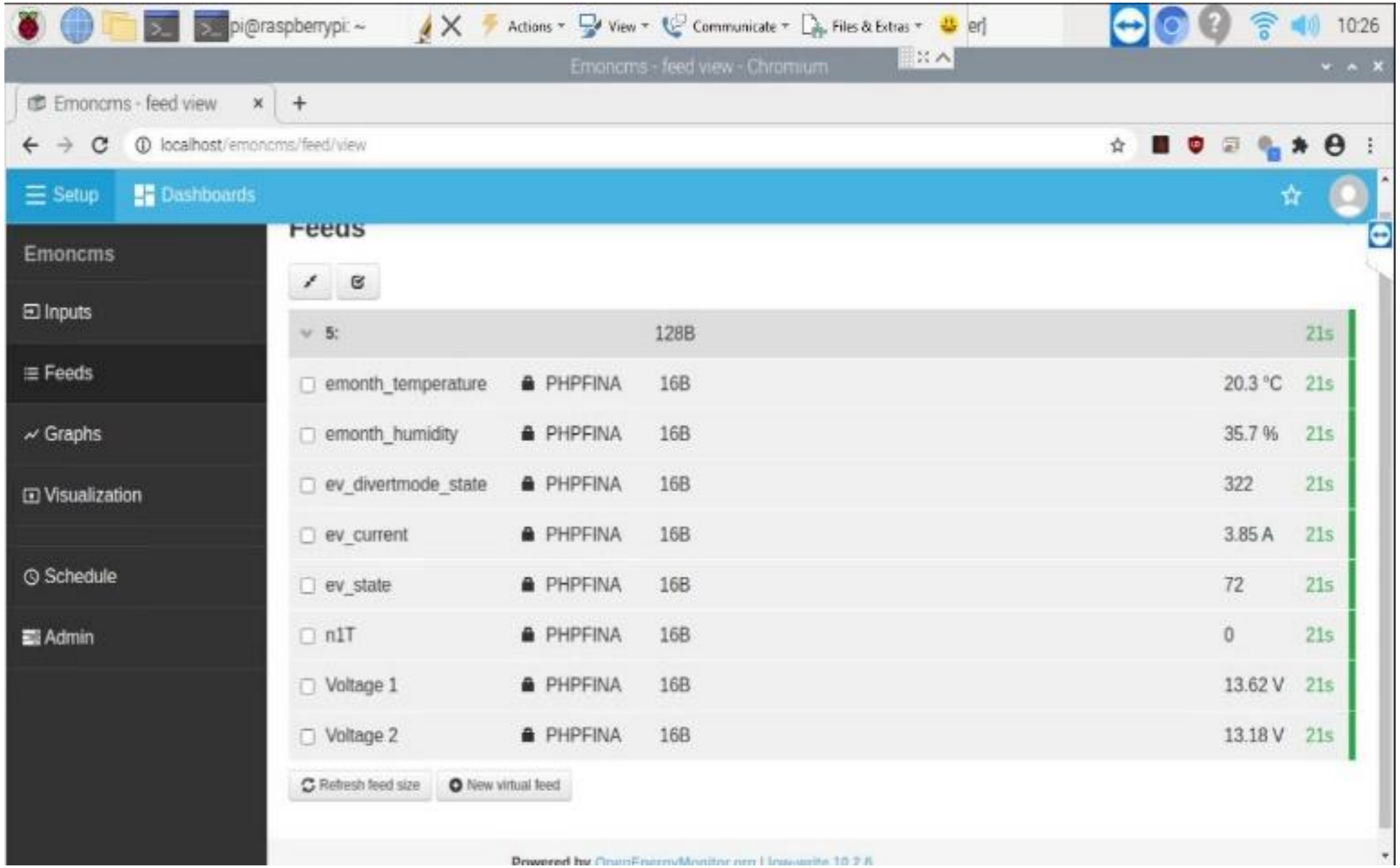
Equipment Used in LAB to Test Prototype



Inputs discovered in Emoncms



Feed for the inputs discovered in Emoncms



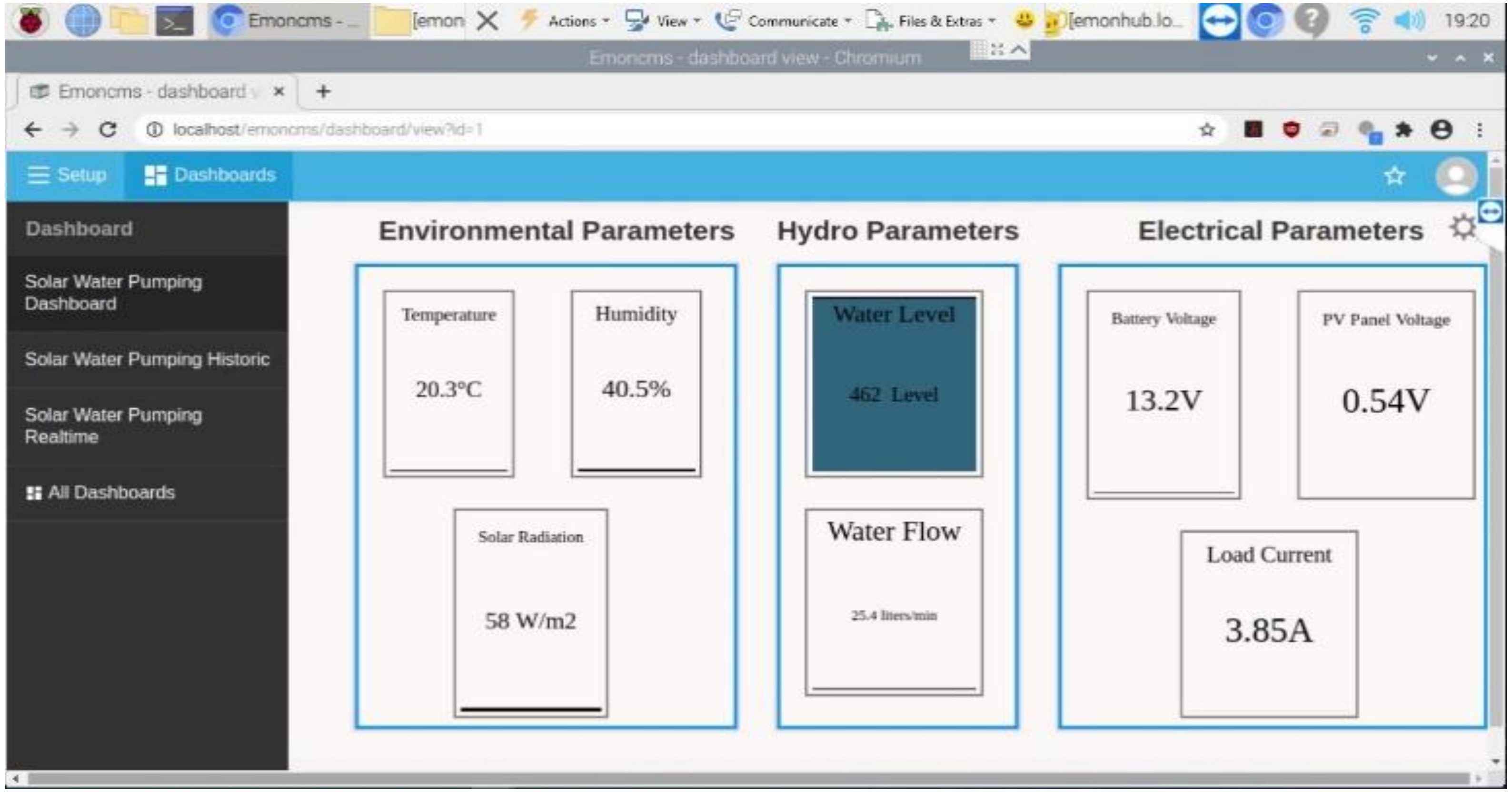
Inputs with discovery number, name and feeds

Input Number	Input Name	Feed name
1	Node Number	Not logged (No feed)
2	Temperature	emonth_temperature
3	Humidity	emonth_humidity
4	Water Level	ev_divertmode
5	Solar Irradiance	ev_state
6	Water Flow Sensor	n1T
7	Battery Voltage	Voltage 1
8	Panel Voltage	Voltage 2
9	Load Current	ev_current

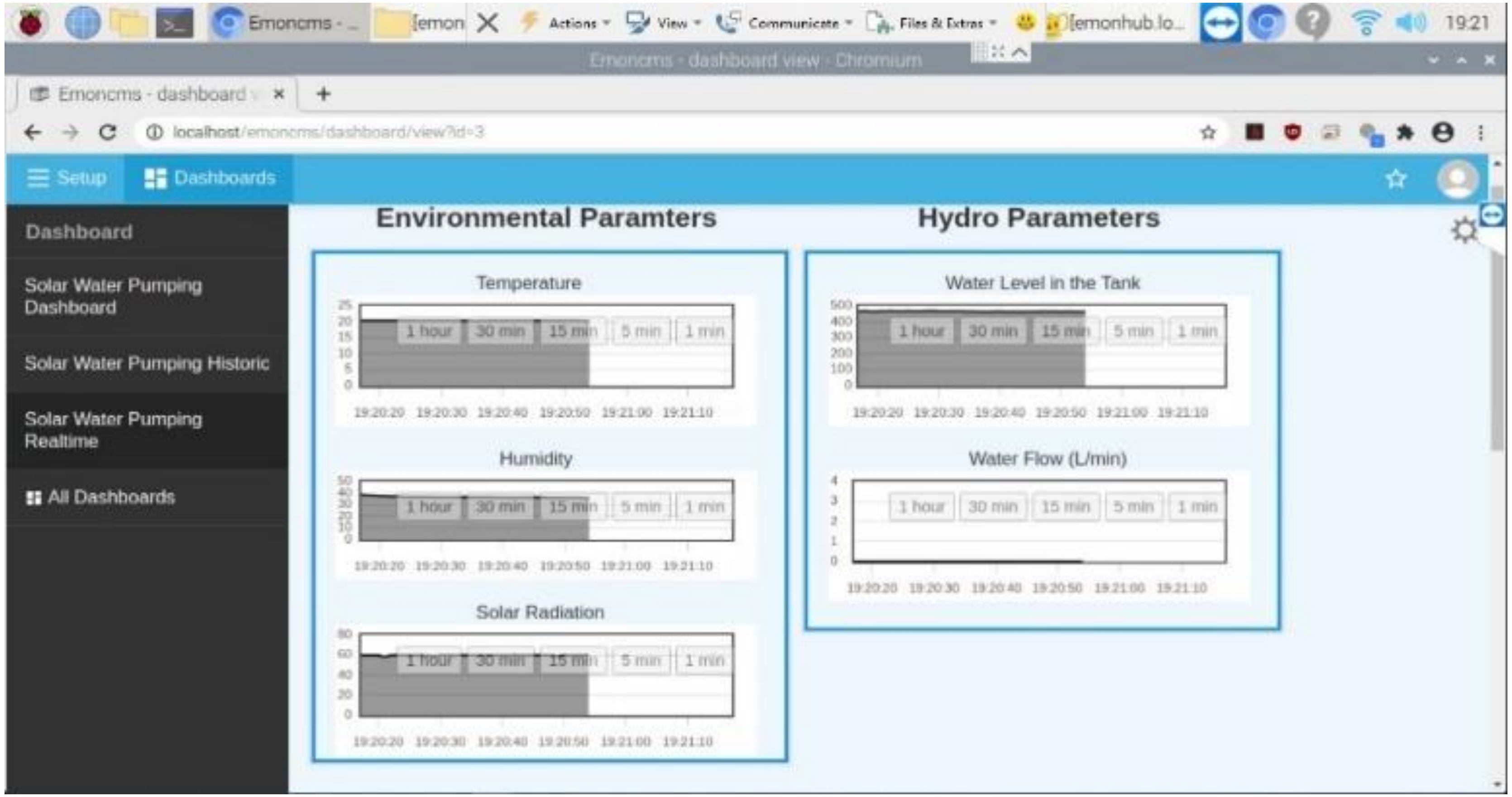
Dashboards reflecting Parameters on Emoncms

- There were three dashboards to capture different parameters of a solar water pumping system
  - Live Dashboard
  - Real Time Dashboard
  - Historic or Logged Dashboard

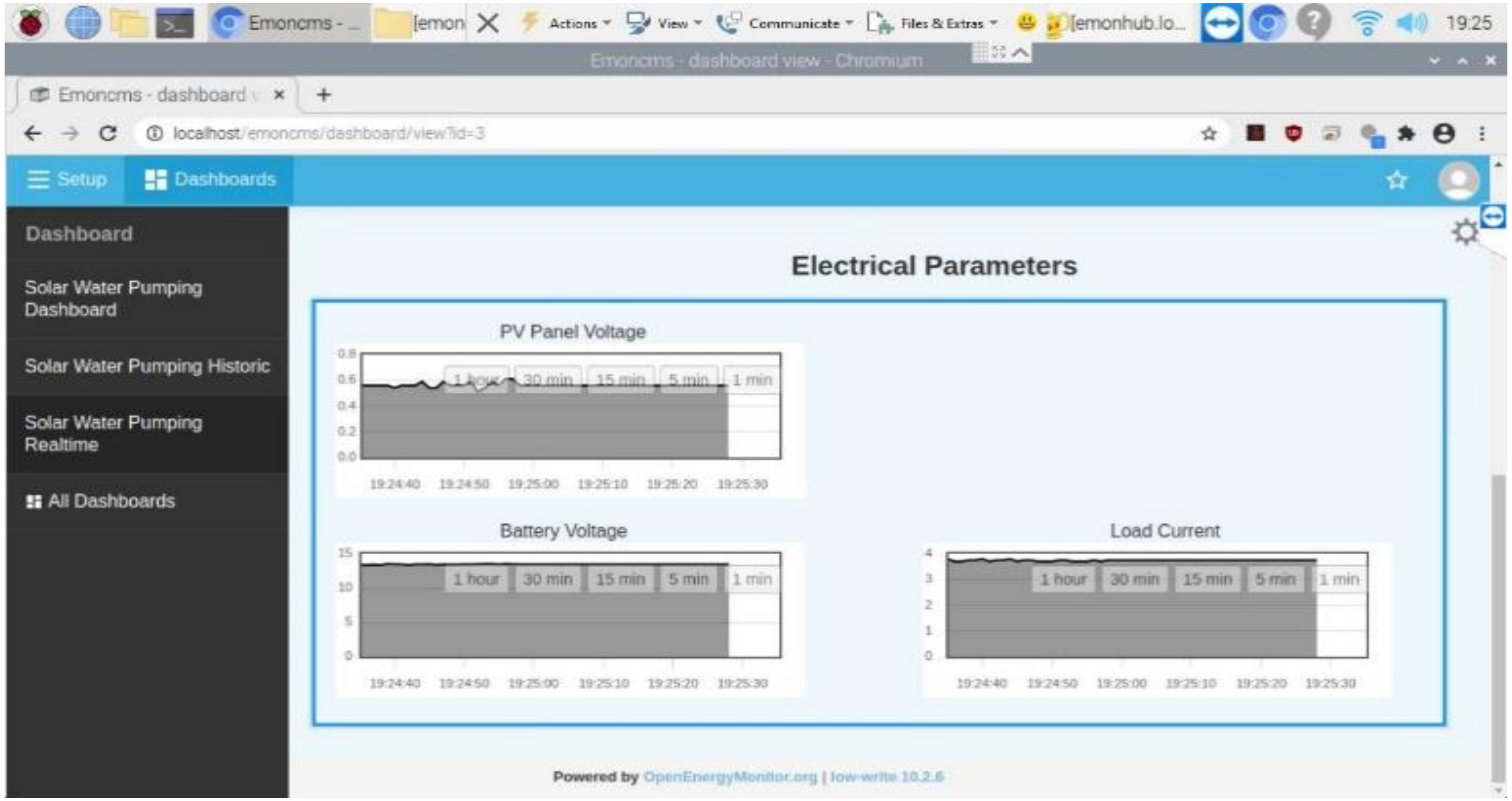
Live Emoncms Dashboard for a solar water pumping system



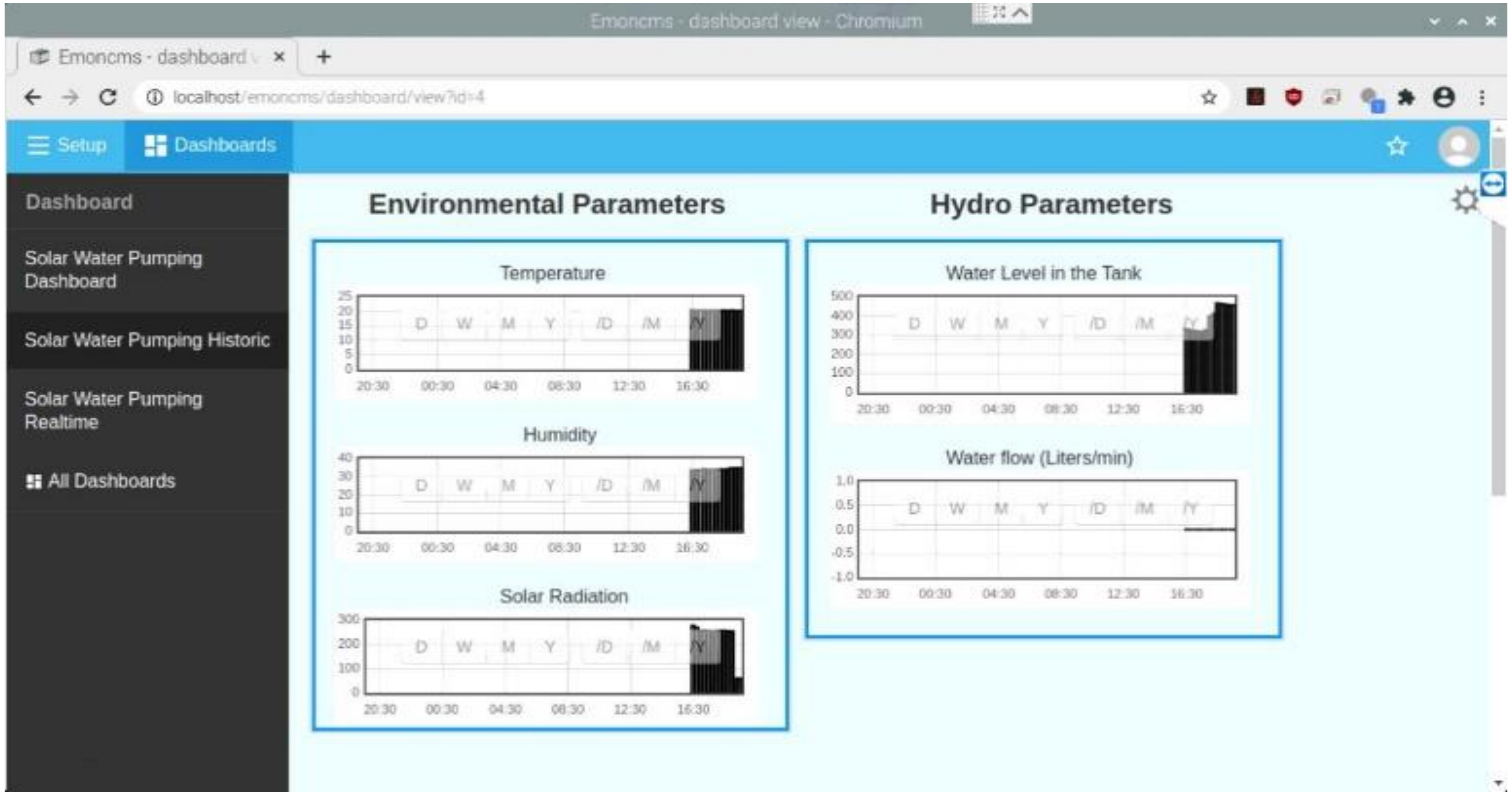
Real time Emoncms Dashboard for a solar water pumping system



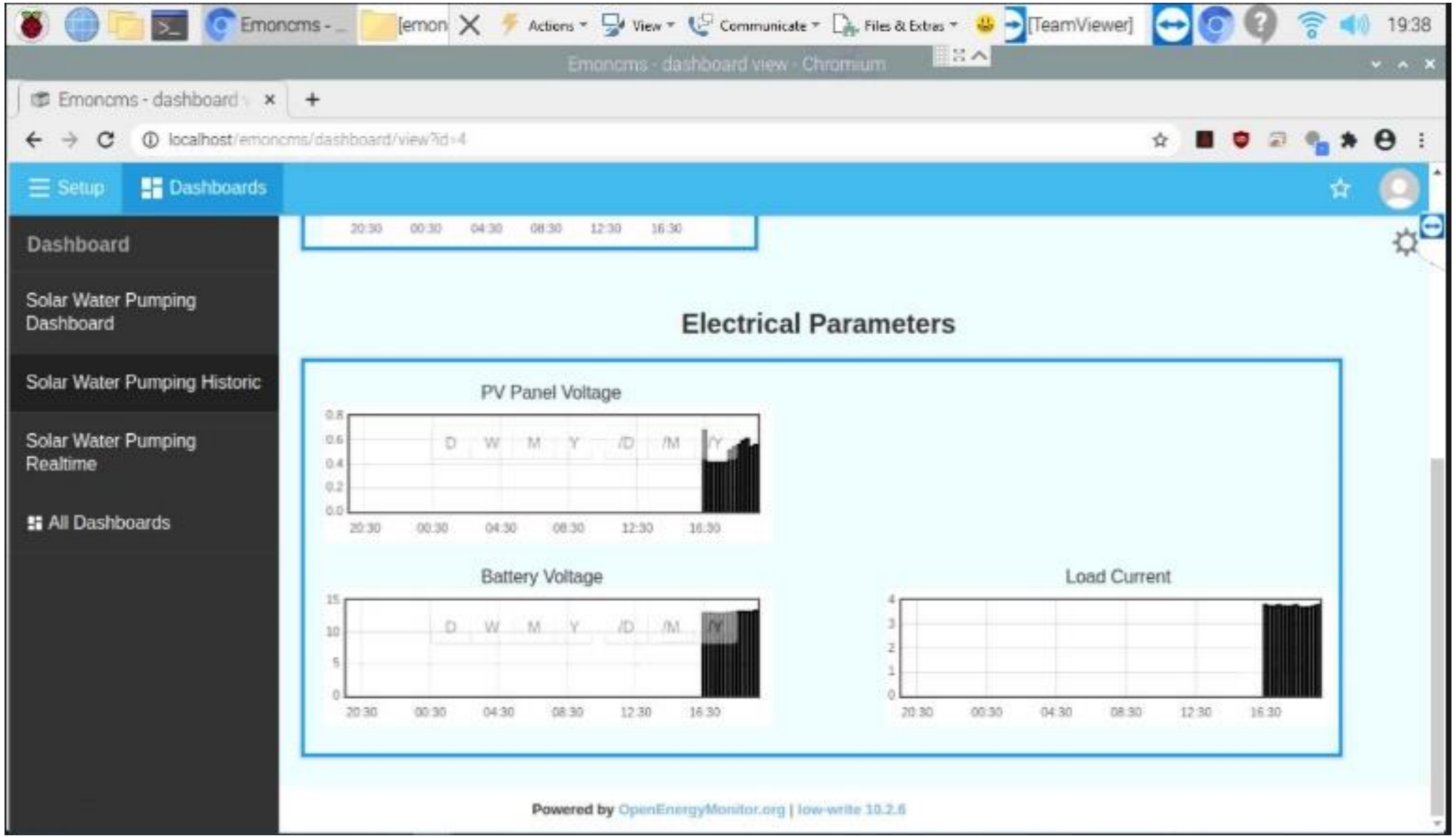
Real time Emoncms Dashboard for a solar water pumping system



Historic or logged data in Emoncms for a solar water pumping system



Historic or logged data in Emoncms for a solar water pumping system



Conclusions

Conclusions

- A detailed design and cost analysis for a solar water pumping system with battery bank was performed in HOMER
- The HOMER simulation summary for system is as follows
  - The PV panel network was 73.8 kW
  - The inverter rating came as 16.7 kW
  - The battery requirement came out to be 450
  - The net present cost for the overall system came out to be $273,670
  - The levelized cost of energy came out as $0.48
  - The operating cost for the system came out to be $5,692.37

Conclusions

- For the designed system, a detailed dynamic analysis was conducted in MATLAB/Simulink, which validated the HOMER software results
- A detailed design and cost analysis for a solar water pumping system with water tank was performed in HOMER
- The HOMER simulation summary for system is as follows
  - The PV panel network was 72.9 kW
  - The inverter rating came as 59.9 kW
  - The net present cost for the overall system came out to be $103,858.30
  - The levelized cost of energy came out as $0.1783
  - The operating cost for the system came out to be $4,649.93

Conclusions

- An Emoncms based SCADA system was implemented to monitor three different categories of parameters for the solar water pumping system
  - Environmental parameters
  - Hydro parameters
  - Electrical parameters
- The data obtained was reflected on three different custom-made dashboards
  - Live Dashboard
  - Real-time Dashboard
  - Historic Dashboard

Research Contribution

Research Contributions

- A comprehensive design and cost analysis for a battery-based solar water pumping system for a selected site in Pakistan was performed in HOMER
- Detailed dynamic modeling for designed solar water pumping system with battery bank in HOMER was performed in MATLAB/Simulink to evaluate the system's feasibility with changing conditions
- A comprehensive design and cost analysis for a water tank-based solar water pumping system for the same selected site in Pakistan was performed in HOMER
- The economical results for both the designed solar water pumping systems were compared to evaluate the most feasible solar water pumping system for Pakistani conditions
- An open-source Emoncms based SCADA was designed to monitor different parameters of a solar water pumping system

Future Work

Future Work

- Dynamic analysis for a solar water pumping system with water tank in MATLAB/Simulink can be performed for the already designed system in HOMER
- The open-source Emoncms based SCADA system can be improved for a wireless system, so that that the data could be controlled and monitored wirelessly
- An email alert system can be incorporated in the already developed SCADA system using Swift-mailer
- A button control can be added to control the motor's ON/OFF from the SCADA system

Publications

Publications

- **Articles in Refereed Publications**
  - Usman Ashraf, M. Tariq Iqbal, Optimised Design and Analysis of Solar Water Pumping Systems for Pakistani Conditions, Energy and Power Engineering Energy, Volume 12, pp 521-542; doi:10.4236/epe.2020.1210032
- **Refereed Conference Publications**
  - Usman Ashraf, M. Tariq Iqbal, An Open Source SCADA for a Solar Water Pumping System Designed for Pakistani Conditions, presented at IEEE computing and communication workshop and conference, CCWC 2021
  - Usman Ashraf, M. Tariq Iqbal, Feasibility Analysis of a Solar Water Pumping System in Pakistani Conditions: A Case Study, presented at IEEE CCECE 2020
- **Regional Conference Publications**
  - Usman Ashraf, Andrew Peddle, Uday Khadodra, M. Tariq Iqbal, Design and analysis of a solar water pumping system for two hectares farm in India, presented at The 29th Annual IEEE NECEC conference St. John's, November 19th, 2020.

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THANK YOU!

ANY QUESTIONS!