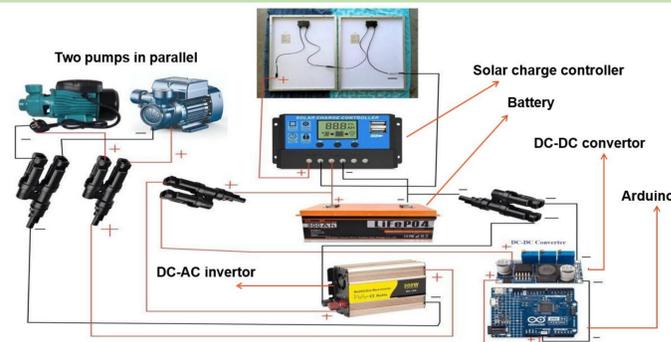


Introduction/Background

- **Problem Statement:** Remote and arid regions often rely on groundwater with high total dissolved solids (TDS), making it unsafe for drinking. Existing desalination systems are costly, energy-intensive, and depend on grid power. There is a clear need for a cost-effective, autonomous desalination solution powered by renewable energy to ensure sustainable access to clean water.
- **Constraints:**
 - RO membrane supports up to 5,000 ppm TDS.
 - Operates on solar energy with 15%–23% efficiency.
 - AI model training limited to ≤ 5 TFLOPS power.
 - Target process optimization efficiency: 80%–90%.
- **Specifications:**
 - Output water TDS between 50–150 ppm (safe for drinking).
 - Pre-treatment removes $\geq 95\%$ of particles $> 5 \mu\text{m}$.
 - Fault detection system achieves $\geq 90\%$ accuracy.
 - Remote commands respond in ≤ 5 seconds.

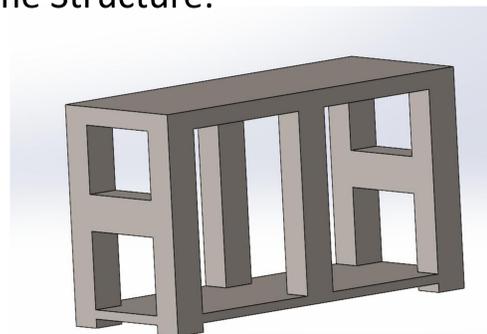
- System footprint is compact: 2.25 m². Provides 6 liters of clean water per minute.
- Requires maintenance only every 3 months.
- Water recovery ratio is efficient at $\leq 2:1$. Ensures TDS ≤ 500 ppm, pH 6.5–8.5, and $\geq 98\%$ contaminant removal.
- Supports real-time monitoring (≤ 1 sec refresh) and fast control (≤ 5 sec).
- AI automatically detects and reports faults.

Connections

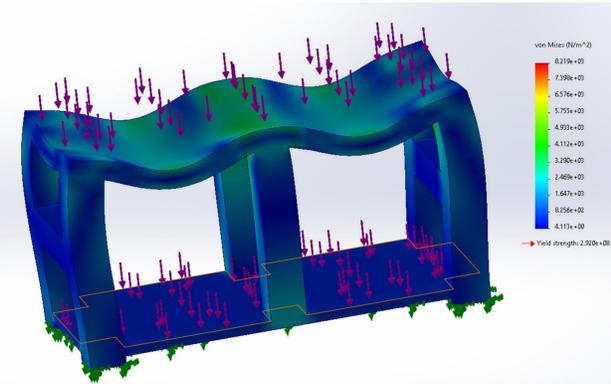


Prototype Design

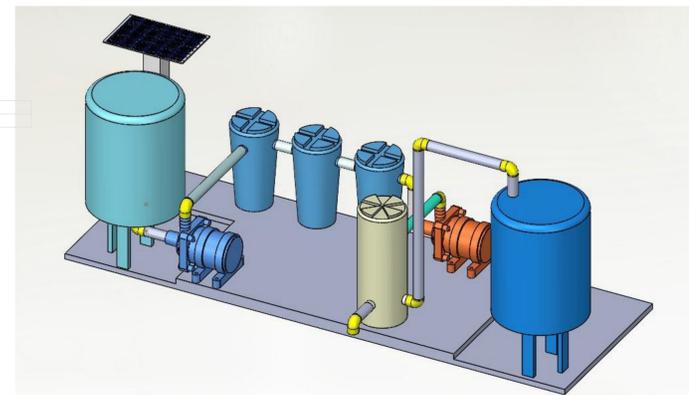
- Frame Structure:



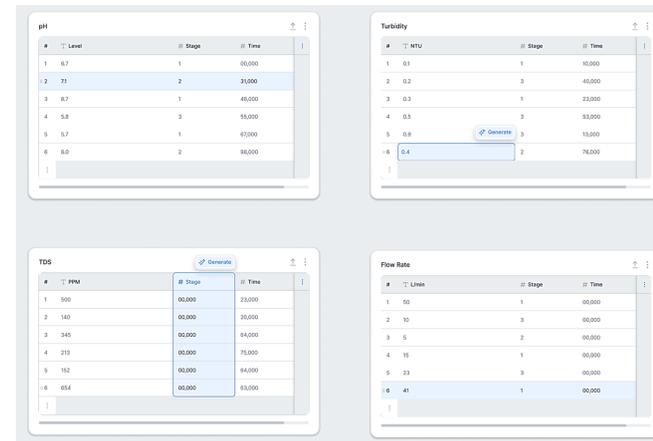
- Stress Analysis:



- SolidWorks Assembly:



- Monitoring Interface



Testing/Validation

Parameter	Field Test Snapshot
Date	2025-04-24
Location	KFUPM - Outdoor Solar Bench
Weather Condition	Sunny
Feedwater TDS	4101.06 ppm
Feedwater Temperature	33.36 °C
pH	7.4
Silt Density Index (SDI)	2.9
Pre-treatment	Sand Filter + Carbon Filter + Sediement
Membrane Type	BW30-4040
Operating Pressure	6.2 bar
Feed Flow Rate	15.5 L/min (gpm)
Permeate Flow Rate	6.2 L/min (~ gpd)
Permeate TDS	104.46 ppm
Brine Concentration	6901.32 ~, ppm
Recovery Ratio	0.4
Energy Consumption	2.1 kWh/m ³
Sensor Faults Detected	None
Maintenance Alert	None
Pump Power Estimate	1650 W
Energy Consumption	~2.1 kWh/m ³
Solar Power Supplied	298.01 W (peak)
Battery Backup Usage	None during test

Conclusion

A multi-stage water treatment system with integrated sensors and automation has been developed and tested. Real-time data collection confirms the system's ability to monitor key parameters like TDS, turbidity, and pH. Preliminary results validate performance and set the stage for future AI integration, offering a smart, efficient, and adaptive approach to water purification.