

Introduction

Background
Saudi Arabia: severe water scarcity. Agriculture uses 80% water (non-renewable). Inefficient irrigation wastes water/energy. Sustainable desert water management is essential for future growth and water security.

Problem Statement
Desert agriculture: low efficiency, no real-time monitoring, high costs. Need: data-driven, automated system for optimized water use, reduced energy, and optimal crop health in arid environments.

Specifications

- Specifications**
- **Monitoring:** EWMA soil moisture ($\lambda=0.2$, $L=3$); Sampling data in 10–15 min.
 - **Hardware:** Pump 10 L/min @ 1.5 bar; IP65 enclosure (-5°C to 55°C).
 - **UI:** Dashboard latency $\leq 15s$; Alert response $\leq 2s$.
- Integrated Specifications**
- **Reliability:** MTTR ≤ 10 min; System 95% reliable (1 month).
 - **Moisture Control:** Within $\pm 5\%$ target VWC.
 - **Pump Operating Time:** Reduce by $\geq 20\%$.

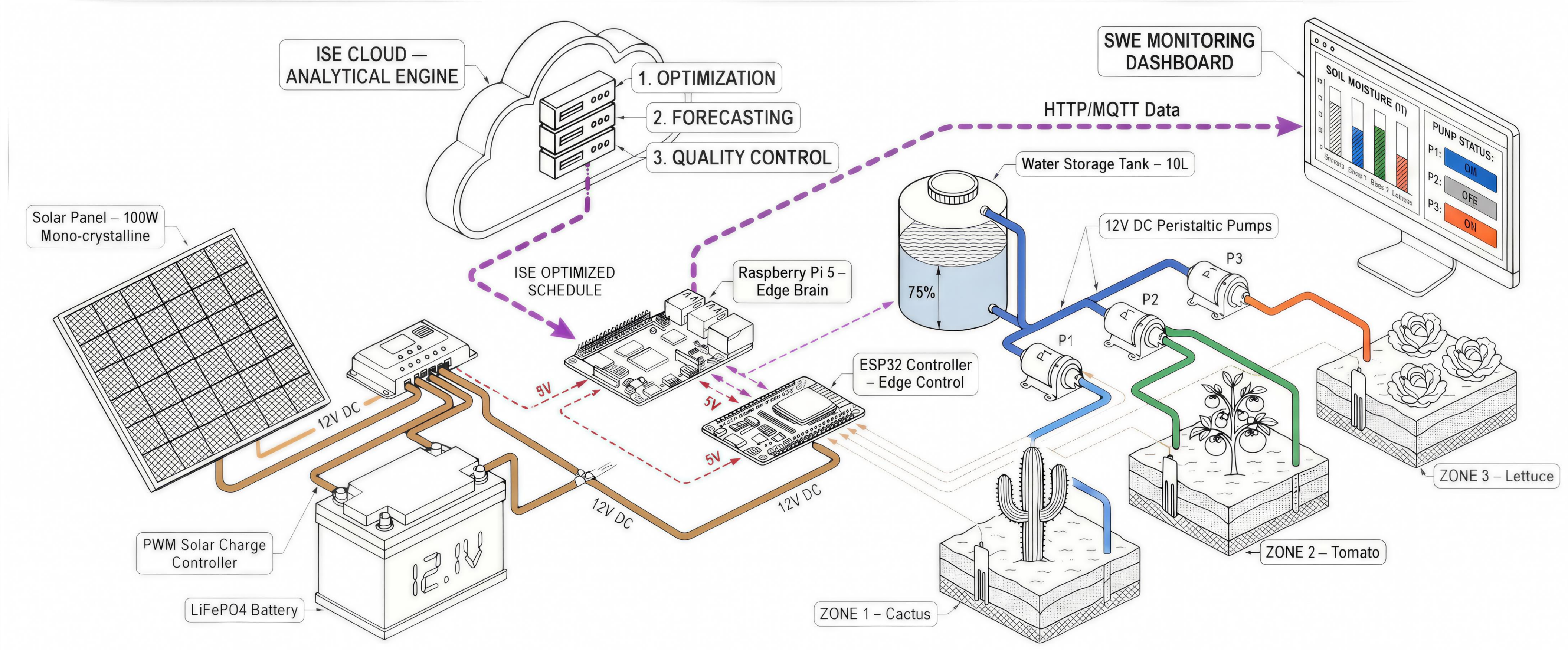
Testing and Validation

Requirement	Target	Actual Result / Proof
Real-time Control	≤ 2.000 s	1.171 s (Safety-critical response time)
Energy Consumption	≤ 1.000 kWh/day	< 1.000 kWh/day (Solar-powered operation)
Moisture Control	$\pm 5\%$ of Target	Maintained within $\pm 5\%$ VWC (Holt-Winters + LP)
Pump Performance	10 L/min @ 1.5 bar	Verified 10 L/min at 1.5 bar pressure
Water Efficiency	$\geq 20\%$ Reduction	Groundwork laid for 20% reduction via Holt-Winters
Optimization Time	≤ 10.000 s	Completed within 10.000 s per run
Durability	IP65 / 55°C	IP65 enclosure verified for desert conditions
Reliability	95% Uptime	Designed for 95% reliability over 1 month

Constraints

- **Performance:** Scheduling $\leq 10s$; Control $\leq 2s$.
- **Water Use:** Max $\pm 10\%$ deviation.
- **System Health:** Pump vibration ≤ 4.5 mm/s RMS; Model retraining max once/week.
- **Energy Consumption:** ≤ 1 kWh/24h.
- **Data/Software:** Decisions logged; Modular architecture.

Prototype Design



Conclusion

SDAWS provides a solution for Saudi water scarcity. It integrates ISE, ME, and SWE for optimized, energy-efficient irrigation. The prototype successfully validated core functionalities, proving its efficacy and offering a robust foundation for sustainable agriculture in arid regions. This innovation delivers a scalable, high-performance path toward global food and water security.