Department of Mechanical & Production Engineering

Advancing Smart Grid Resilience in Uganda: The Role of Robotic Systems in Automated Power Line Monitoring and Fault Detection

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Background and Objectives

- Uganda's grid faces persistent reliability challenges due to manual inspection methods.
- Manual inspections are time-consuming, reactive, and prone to delayed fault detection.
- This research investigates using *drones and mobile robots for automated power line inspection*.
- Objective: Enhance grid resilience and enable predictive maintenance using robotic systems.

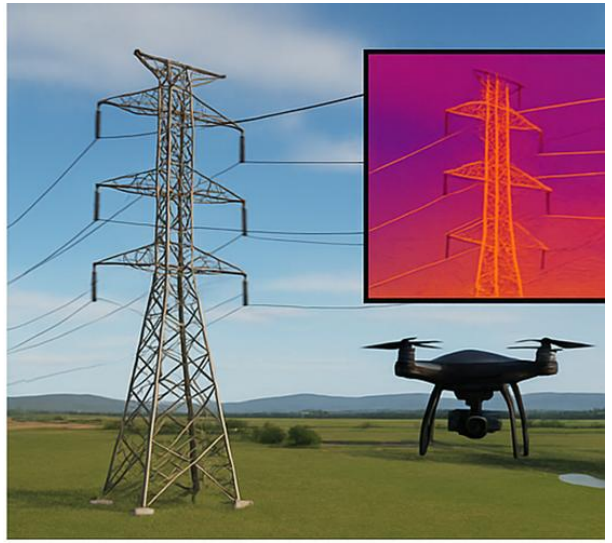
Methodology

- Mixed-methods: literature review + simulation.
- Data from UETCL used to identify current gaps.
- ROS and Gazebo used to simulate UAVs and mobile robots.
- Key metrics: Inspection coverage, fault detection accuracy, inspection cycle time.
- Digital Maturity Index (DMI) proposed to assess integration readiness.

Methodology

Simulations: UAV

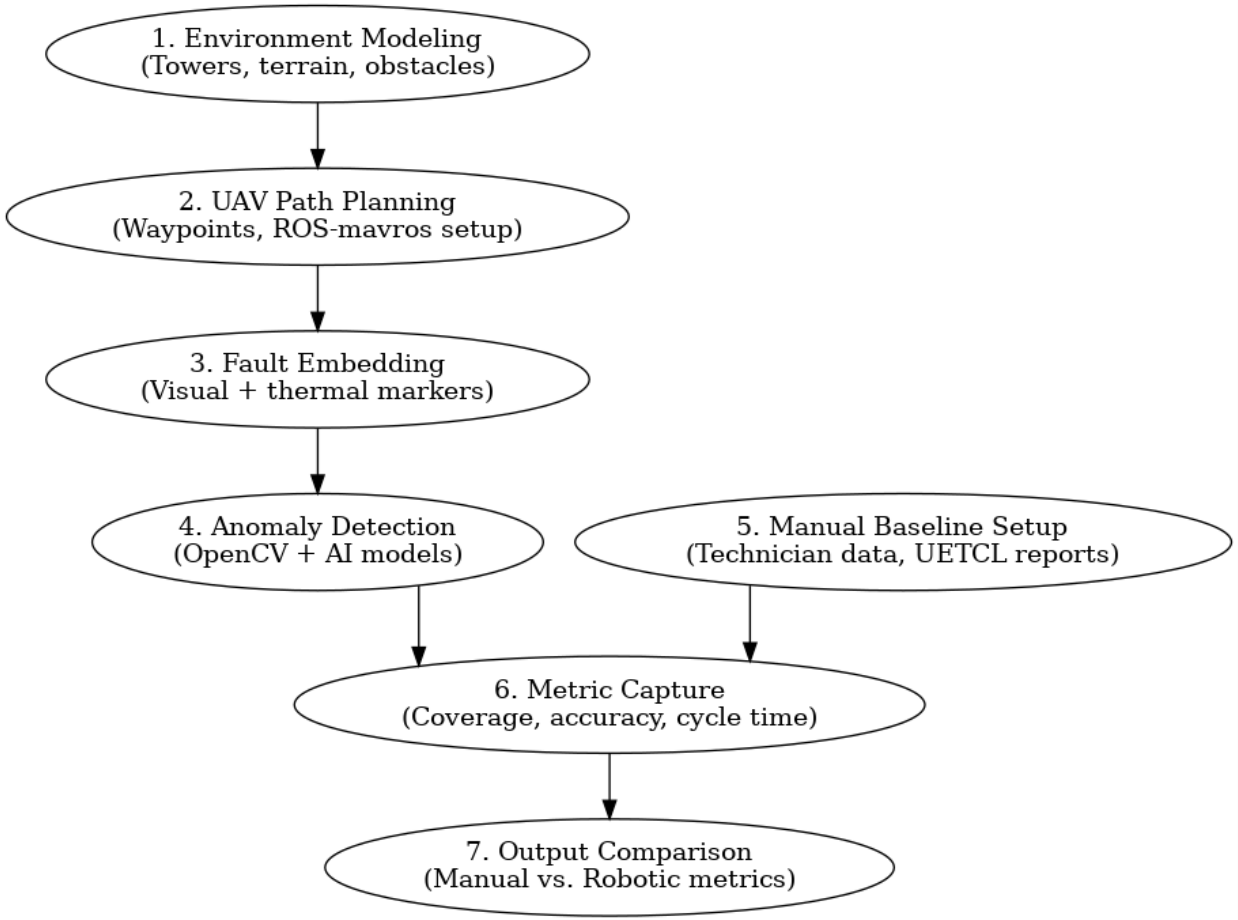
Parameter	Value / Description
Simulation Platform	ROS (Robot Operating System) with Gazebo
Terrain Model	1.5 km × 1 km semi-rural environment with elevation
Transmission Line Type	132 kV double-circuit steel lattice towers
Number of Inspection Points	15 tower structures and 30 spans
Weather Condition Simulated	Clear daytime; light wind (5–8 km/h)
UAV Model	Quadrotor with GPS, IMU, RGB + thermal camera
Flight Altitude	20–30 meters above ground level
Flight Speed	3–5 m/s (adjusted for imaging detail)
Ground Robot (optional task)	Wheeled UGV for substation base inspection
Fault Types Simulated	Corroded connectors, broken insulators, hotspots
Imaging Resolution	RGB: 4K; Thermal: 640×480 (FLIR-equivalent)

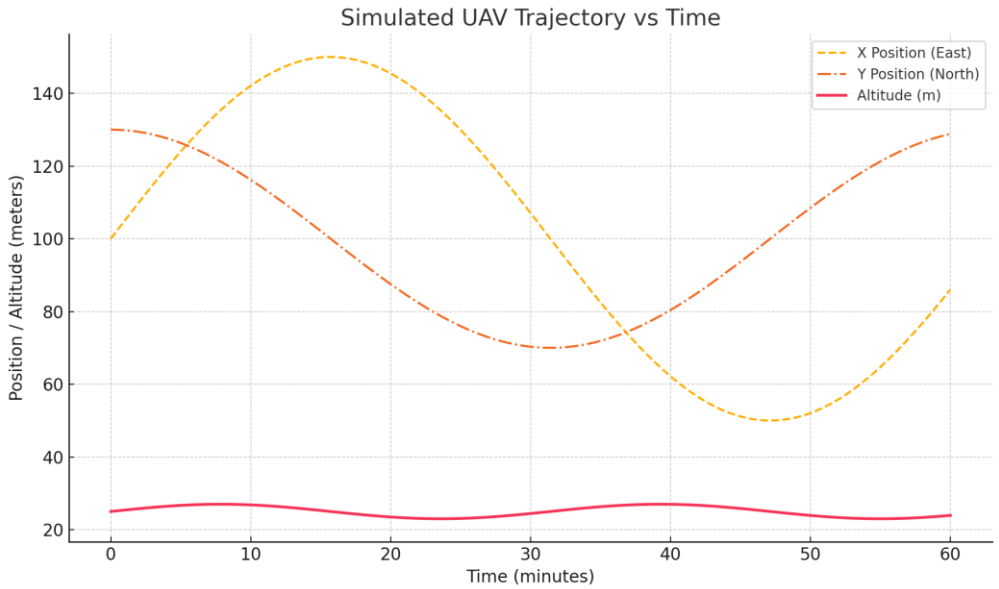


Simulated deployment scenarios of UAV equipped with thermal and optical sensors

Methodology

Simulations: UAV





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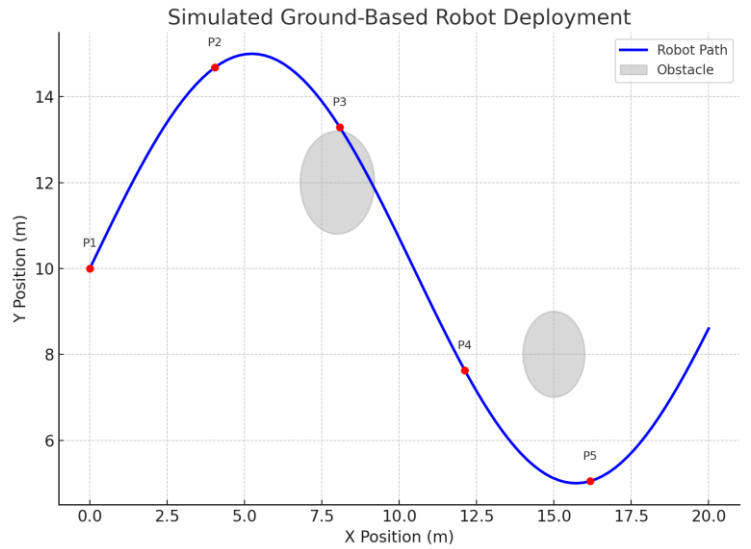
Methodology

Simulations: Ground-Based Robot

Simulated Ground-Based Robot Deployment

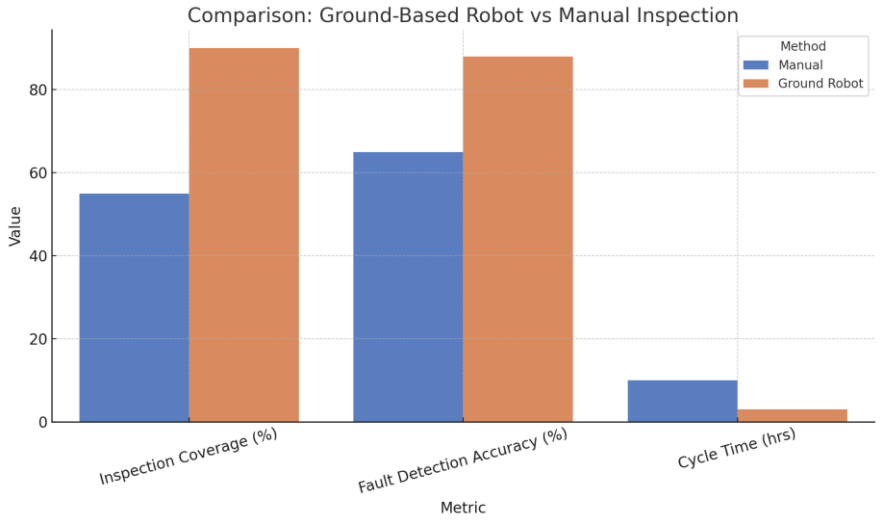
Simulation protocol

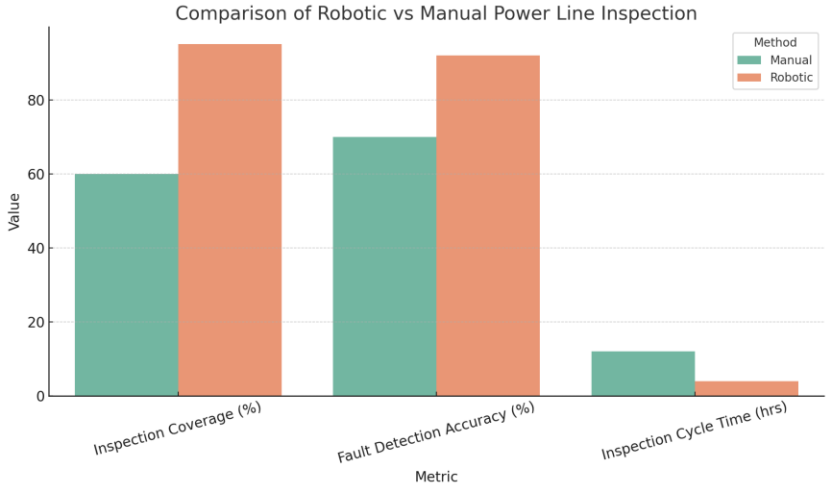
	Parameter	Value/description
1	Simulation platform	ROS + Gazebo
2	Environment type	Substation layout with towers and poles
3	Inspection length	30m x 30m area
4	Obstacles simulated	Concrete bases, equipment shades
5	Robot type	Wheeled UGV
6	Robot speed	0.5-1 m/s
7	Sensor modules	LiDAR, RGB Camera, Ultrasonic
8	Types of faults simulated	Cracks, obstruction, loose connections



Key Findings

- Robotics reduced inspection time by over 60%.
- Thermal + AI imaging improved fault detection to 92%.
- Ground robots are effective in poor weather and at substations.
- Robotics improve planning, coverage, and reliability.





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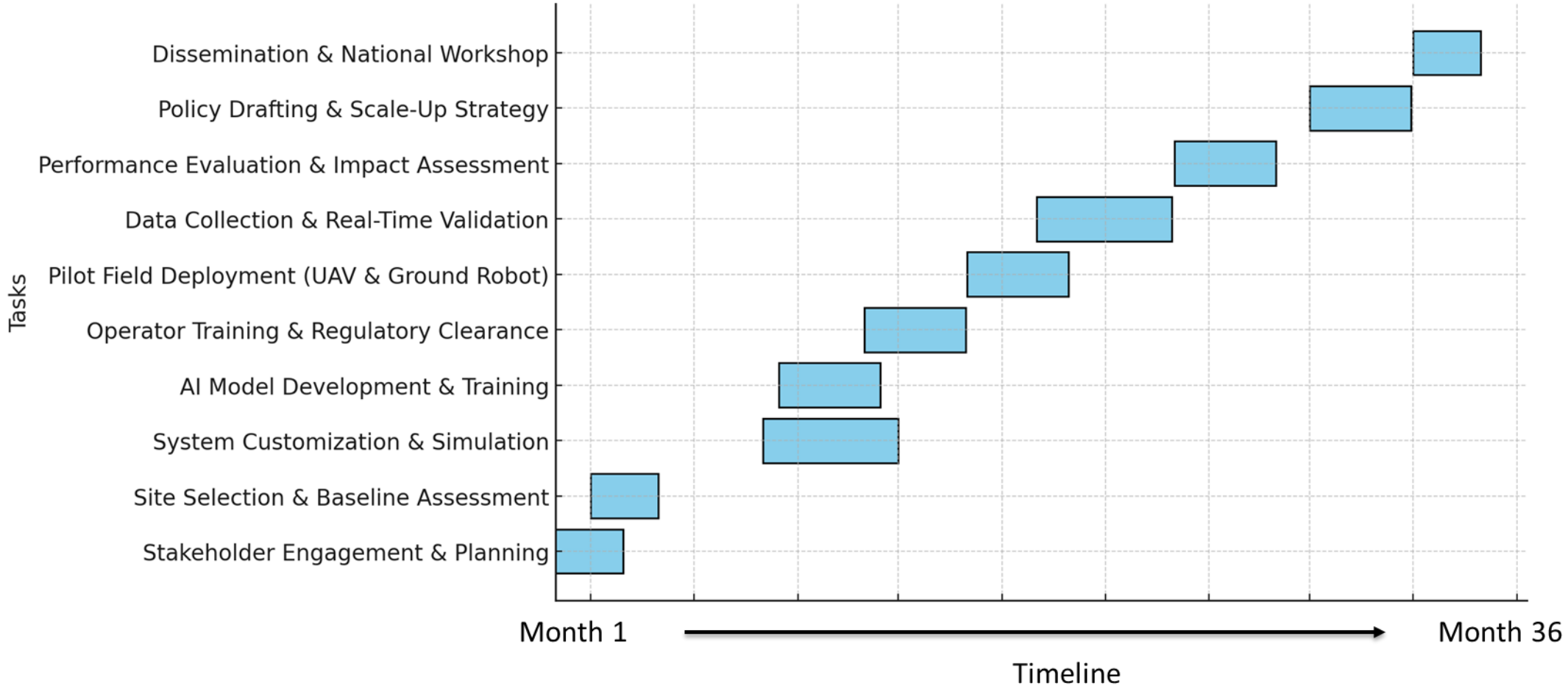
Proposed pilot roadmap for real-world implementation



Relevance and Implications

- The project supports Uganda's smart grid and digitalization goals.
- Aligns with SDG 7 – Affordable and Clean Energy.
- Enables predictive maintenance and reduces outages.
- Framework helps policymakers define integration standards.
- Highlights workforce training and local robotics capacity.

Thank you!