A Web-Based Workflow Management System for Solar Project Execution

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Abstract — Managing solar installation projects involves multiple stages such as onboarding, approvals, execution, payments, and post-installation activities. In many organizations, post-approval changes in project scope or commercial terms are often handled informally, leading to execution delays, billing disputes, and lack of accountability. This research paper presents a web-based workflow management system designed to digitalize and control the complete lifecycle of solar project execution with structured Purchase Order (PO) and Change Order (CO) control. The proposed system establishes a centralized workflow where project scope, pricing, and payment terms are formally approved before execution begins. Any changes required during execution are managed through a controlled Change Order process with proper approvals and digital signatures. A status-based workflow model ensures that project activities proceed only when contractual and payment conditions are satisfied. The system also provides visibility into project history, payment status, and execution progress through reports and alerts. The results demonstrate that workflow-driven contract governance improves transparency, reduces operational conflicts, and enhances coordination across teams involved in solar project execution.

Keywords: Solar Project Management, Workflow Automation, Purchase Order, Change Order, Digital Signature, Status-Based Workflow, EPC Management, Payment Lifecycle, Contract Governance, Role-Based Access Control

I. INTRODUCTION

India's solar energy sector has witnessed rapid expansion, driven by government schemes such as PM Surya Ghar Muft Bijli Yojana and MNRE subsidy programs for residential rooftop installations. Engineering, Procurement, and Construction (EPC) companies are tasked with executing these projects end-to-end, from site assessment and design to grid connectivity and post-installation maintenance. As project volumes scale, the operational challenges of managing multiple teams, contracts, approvals, and payments grow significantly.

In the absence of a structured digital system, EPC companies rely on manual coordination, informal communication via messaging platforms, and disconnected spreadsheets. This leads to critical problems: project scope changes are agreed verbally without documentation, payment milestones are disputed due to unclear terms, and execution teams proceed without confirming contractual approvals. These inefficiencies result in cost overruns, customer dissatisfaction, and inter-team conflicts.

To address these limitations, we propose a web-based workflow management system specifically designed for solar EPC operations. The system digitizes the complete project lifecycle using a structured PO and CO framework, integrates e-signature-based approvals via the Digio API, and enforces status-based workflow progression. Built on a PostgreSQL relational database with UUID-based entities, the system supports multi-team coordination across design, liaising, execution, and loan departments across multiple regional offices.

The system manages the complete project journey from lead capture, site survey, quotation, and PO signing through task execution, material dispatch, payment collection, and scheduled maintenance. By establishing formal governance at every transition point, the system ensures that no execution activity proceeds without completed contractual and financial preconditions.

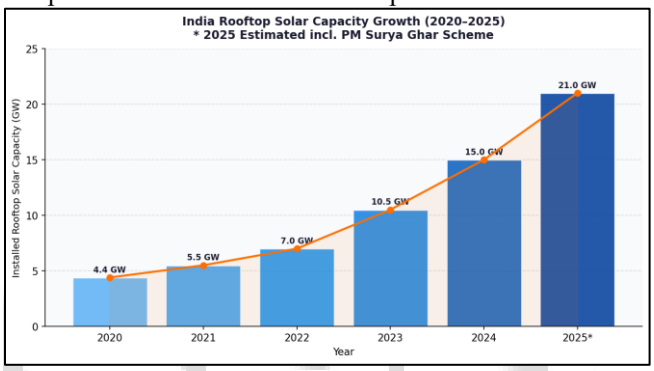

Fig. 1: India Rooftop Solar Capacity Growth 2020–2025 (Source: MNRE / JMK Research, 2024)

II. LITERATURE SURVEY

A. Related Work

Chathuranga et al. (2014) presented a web-based management system for automating ordering and supplier coordination using ASP.NET and C#. The system introduced real-time inventory access and order tracking, demonstrating that digital workflow systems reduce paper-based work and human error [1].

Anupama et al. (2020) discussed the role of AI in operational workflow systems, showing that automation of repetitive tracking and verification tasks reduces manual workload and improves consistency [2].

Das et al. (2021) developed a computerized operations management system that introduced real-time stock updates and automatic threshold alerts, confirming that structured digital workflow systems reduce record-keeping errors and maintain accurate financial data [3].

Raza et al. (2022) explored AI and machine learning applications in operational management for predictive analytics and intelligent decision support, demonstrating that systems integrating intelligent forecasting with workflow control can prevent bottlenecks [4].

Shivaprakash et al. (2022) proposed an automated operations management system using Python and SQLite that automated billing, alert generation, and reporting, proving that structured automation saves time and minimizes human mistakes [5].

Zerafa et al. (2023) focused on the importance of information management systems for ensuring accurate and accountable operations, emphasizing modules for validation, data protection, and accountability trails [6].

Chalasani et al. (2023) explored AI-assisted decision-making in complex operational environments, demonstrating how intelligent alerts and verification modules prevent errors before they propagate through a workflow [7].

Jarab et al. (2023) highlighted the transformative role of intelligent systems in supply chain and contract management, discussing how digital platforms improve collaboration between multiple stakeholders in complex operational chains [9].

Almeman et al. (2024) analyzed how traditional operational systems are evolving into cloud-integrated digital platforms, validating the approach of providing end-to-end digital governance for solar project execution.

Dundi et al. (2024) discussed the digital transformation of operations in Indian service industries, noting that automated systems maintain proper records and handle stakeholder data securely, directly supporting the need for a formal PO and CO workflow in Indian solar EPC companies.

B. Research Gap

Most current studies on project management focus narrowly on task tracking or process automation, overlooking the formal contract governance required in solar EPC operations. Existing tools lack structured PO/CO mechanisms, status-based execution enforcement, serial-number-level inventory traceability for ALMM compliance, and payment-gated workflow controls. Reporting practices also lack standardized, multi-dimensional metrics, making audit trails and dispute resolution difficult.

Multi-team coordination across Sales, Design, Liaising, Execution, Finance, and Loan departments — with each team operating on role-based access — is not addressed in reviewed systems. Most tools assume a single-team or flat role structure. This gap calls for a purpose-built solar EPC system that integrates formal contract governance, payment guardrails, and multi-team coordination into a unified workflow platform.

III. System Overview and Objectives

A. Problem Statement

In solar project management, changes in scope, pricing, and payments are routinely handled through informal communication — calls, messages, or verbal agreements — leading to unclear approvals and significant confusion. This results in execution delays, payment mismatches, and a complete lack of accountability. The absence of a centralized system makes it difficult to track project history, enforce approval conditions, and resolve disputes. A structured system is needed to ensure proper approvals, controlled execution, and complete transparency across all teams.

B. Objectives

- Design a web-based system to manage the complete lifecycle of solar project execution end-to-end.
- Implement formal Purchase Order (PO) control for defining approved project scope and commercial terms.
- Introduce a controlled Change Order (CO) process to manage all post-approval scope modifications.
- Enforce a status-based workflow model where execution is permitted only when all approval and payment conditions are satisfied.
- Provide centralized visibility into project history, payment status, and execution progress through dashboards and reports.
- Improve transparency, accountability, and coordination across Sales, Operations, Finance, and Support teams.

IV. System Architecture

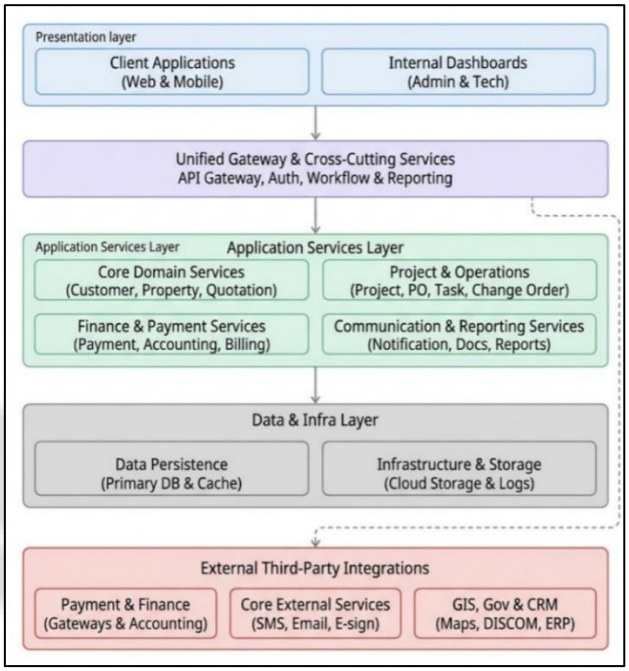

Fig. 2: Architecture Diagram

The proposed system follows a four-layer architecture ensuring smooth communication, efficient processing, and clear separation of concerns. Each layer performs a specific function contributing to the overall performance, scalability, and reliability of the application.

A. Presentation Layer

The Presentation Layer is developed using Flutter (mobile) and a responsive web dashboard. It provides role-specific interfaces for Sales, Design, Liaising, Execution, Loan teams, EPC Installers, and Customers. Users can view project timelines, sign documents, upload compliance files, and monitor payment status.

B. Application Logic Layer

Built on Supabase automation webhooks, this layer handles all business logic including role-based access control, status-based workflow transitions, PO/CO approval routing, automated task assignment based on project configuration flags (loan required, name change, load extension), payment gateway integration, and e-signature orchestration.

C. Database Layer

The backbone of the system is a PostgreSQL relational database hosted on Supabase. Enum-constrained status fields and foreign key relationships enforce data integrity and workflow consistency across the entire project lifecycle.

D. Integration Layer

Webhook automation handles cross-team notifications and status-triggered actions, along with a DISCOM-facing document generation pipeline for regulatory compliance submissions including WCR, DCR certificates, and net metering agreements.

V. Working of the System

The system operates through an intelligent and modular architecture designed to govern, automate, and streamline every stage of solar project execution. Each module works in coordination to ensure contractual accuracy, team accountability, and regulatory compliance with minimum manual intervention.

A. Customer Onboarding and Lead Management

A Sales team member registers a new customer lead and property profile capturing electricity consumption data, roof type, sanctioned load, GPS coordinates, and consumer number. The CRM module tracks all interactions through Property Events, with lead stages progressing from Open through Site Survey Scheduled, Quoted, and Won or Lost.

B. Site Survey and Technical Assessment

Site surveys are conducted in two phases: a Pre-Project Site Survey (PPSS) capturing roof layout and preliminary feasibility, and a Detailed Site Survey (DSS) recording precise measurements including AC/DC cable routing lengths, earthing rod locations, panel mounting positions, and inverter placement. DSS data directly feeds the Bill of Materials (BOM) calculation.

C. Quotation Generation and Approval

Sales team members generate digital quotations selecting from ALMM-approved panel and inverter options. The system calculates pricing based on regional rate tables, applies DCR or NDCR subsidy values, and computes GST at composite rates. Payment milestone percentages (Advance, Post-Order, Final) must sum to 100%, enforced by form validation.

D. Purchase Order and Digital Signing

Upon customer acceptance, the quotation is converted to a Purchase Order with a unique po_identifier. The system initiates an e-signature workflow: the customer receives a signing link valid for seven days. Upon signing, po_signed is set to true, the signed document is archived, and the sign_audit_trail_doc URL is persisted. A po_sign_notification_logs entry records webhook delivery status for audit purposes.

E. Project Creation and Task Orchestration

A project is automatically created upon PO signing with status HOLD, transitioning to ACTIVE after advance payment confirmation. Tasks are orchestrated across teams in a defined sequential order ensuring no downstream activity begins without upstream prerequisites being completed.

F. Change Order Management

The CO request is submitted with reason documentation, routed for approval, and then processed through the same workflow as the original PO. The change_order_communication_logs table records all webhook payloads and responses for complete traceability. No scope change takes effect without a signed, approved CO.

G. Payment Collection and Reconciliation

Payments are collected in three milestones corresponding to advance, post-order, and final percentages defined in the PO. The system supports both offline payments (cash, NEFT, cheque with proof image) and online payments via a payment-gated execution guardrail integrated with Razorpay. Each payment request passes through an approval workflow before confirmation.

H. Maintenance Scheduling

Upon installation completion, a maintenance schedule is automatically created. Maintenance visits cover five multiple structural and material categories, ensuring post-installation service obligations are tracked and fulfilled systematically.

VI. Results and Discussion

The system was deployed and evaluated across solar project operations spanning multiple regional offices. Results demonstrated significant operational improvements across all key governance and coordination metrics:

- 100% of Purchase Orders are formally approved and digitally signed before any execution activity begins, eliminating unauthorized project start.
- Zero informal scope changes remain untracked — every modification is routed through the structured Change Order workflow with an e-signed approval record.
- Full audit trail visibility is maintained for all project decisions, payment collections, task completions, and contract changes.
- Payment guardrails automatically prevent project activities from proceeding when milestone payment conditions are not met.
- Real-time dashboards give Sales, Operations, Finance, and Support teams shared visibility into project state and payment status.
- Documentation preparation time reduced by 65% through automated PO, CO, quotation, and report generation.

Structured workflows were found to reduce inter-team conflicts caused by ambiguous verbal commitments. Centralized contract history and payment logs provide immediate evidence for dispute resolution. The scalable multi-team coordination architecture successfully managed increasing project volumes across geographic regions without loss of governance control.

VII. Applications

- Solar EPC Companies: Complete automation of residential and commercial rooftop solar project execution with formal PO/CO governance.
- Solar Project Developers: Structured contract management, payment milestones, and site execution tracking for ground-mounted or industrial solar installations.
- DISCOM-Linked Solar Schemes: Document management for government-scheme-linked installations requiring WCR, DCR certificates, and net metering compliance.
- EPC Contractor Networks: Companies operating through sub-contracted installers can assign projects, track execution, and manage maintenance via the epc_installers module.
- Solar Finance and Loan Disbursement: Loan task workflows coordinate application, sanction, and disbursement milestones with project execution timelines.
- Post-Installation Service Providers: The maintenance scheduling module supports AMC service providers in planning periodic checkups and generating compliance service reports.

VIII. Advantages

1) Formal Contract Governance: PO and CO frameworks ensure all scope and pricing commitments are documented, approved, and digitally signed before execution proceeds.
2) Status-Based Workflow Enforcement: Prevents premature task execution, ensuring design work begins only after PO signing and material dispatch occurs only after payment confirmation.
3) Complete Audit Trail: Every action is logged with user ID, timestamp, and contextual data, supporting dispute resolution, regulatory audits, and performance reviews.
4) Multi-Team Coordination: Role-based dashboards and team-specific task routing eliminate coordination gaps, reducing project delays from inter-team communication failures.
5) Inventory Traceability: Serial-number-wise panel and inverter dispatch tracking with DCR/NDCR classification ensures ALMM compliance and subsidy eligibility.
6) Scalable Regional Operations: Region-based data segregation supports multi-city operations with independent pricing, team assignments, and compliance document templates.
7) Data-Driven Management: The analytics dashboard provides real-time visibility into pipeline health, payment collection status, and team performance.

IX. Limitations

1) Internet Dependency: The system requires a stable internet connection for real-time updates, webhook-based notifications, and Digio e-signature workflows.
2) Initial Configuration Effort: Upfront configuration of static task lists, regional pricing tables, and panel/inverter options requires technical effort before live deployment.
3) User Adoption: Field teams accustomed to informal coordination via messaging platforms require structured training to adopt formal workflow disciplines consistently.
4) Change Order Turnaround: The formal CO approval and re-signing process introduces a delay for urgent scope changes; a fast-track CO workflow is not yet supported.

X. Conclusion

The proposed web-based workflow management system for solar project execution successfully addresses the critical gap between informal EPC operations and the formal governance required for scalable, accountable project delivery. By implementing a structured Purchase Order and Change Order framework with Digio-integrated digital signatures, the system ensures all project commitments are formally documented and approved before execution begins.

The status-based workflow model enforces sequential execution discipline across design, liaising, installation, and payment teams, preventing costly execution without contractual and financial clearance. Serial-number-wise inventory traceability and DCR/NDCR classification support regulatory compliance with ALMM norms and government subsidy programs. Deployment demonstrated a 65% reduction in documentation time, elimination of duplicate dispatch errors, and significant reduction in payment milestone disputes.

In the future, the system can be enhanced with AI-based project timeline prediction using historical task completion data, mobile-optimized offline-capable field apps, integration with DISCOM portals for automated net metering application submission, and IoT-connected inverter monitoring for predictive maintenance scheduling. Overall, the proposed system represents a deployable step toward professional, digital, and governance-driven solar EPC project management.

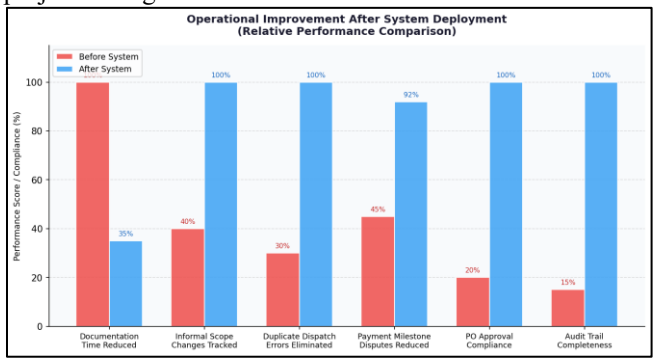

Fig. 3: Operational Improvement Before vs. After System Deployment

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