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Secure Escrow Bond Smart Contract For Trustless Transactions On The Solana Blockchain

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Abstract: With the rapid growth of decentralized finance (DeFi) and peer-to-peer transactions on high-performance blockchains, managing trustless escrow for assets between untrusted parties has become essential for security, transparency, and efficiency. Traditional centralized escrow services are slow, expensive, and vulnerable to counterparty risk. This project proposes a Secure Solana Escrow Smart Contract System that automates escrow creation, fund deposit, conditional release, and dispute handling using on-chain logic. The system comprises two primary modules: (1) Escrow Creation and Management, and (2) Intelligent Transaction Execution and Release. In the first module, users create escrow accounts via a web-based dApp; the smart contract (developed in Rust using the Anchor framework) validates parties, amount, and release conditions. The second module automatically releases funds upon condition satisfaction or enables refund/cancellation. The contract leverages Solana's Program Derived Addresses (PDAs) for secure fund holding, Solana Web3.js for client interaction, and SPL token support for fungible/non-fungible assets. All transactions are recorded immutably on the Solana blockchain, enabling real-time monitoring and auditability. The system is developed using Rust, Anchor framework, Next.js/React frontend, and Solana RPC nodes. Experimental testing on Solana Devnet demonstrates that the system achieves transaction confirmation in under 400 milliseconds with 99.2% success rate and near-zero compute unit wastage compared to manual or Ethereum-based escrow solutions. This project delivers a scalable, low-cost, and tamper-proof escrow solution for modern DeFi ecosystems, contributing to the advancement of trustless Web3 applications.

Index Terms – Escrow Bond ,Solana Blockchain, Escrow Smart Contract, Anchor Framework, Rust, Decentralized Finance (DeFi), Trustless Transactions, Program Derived Addresses (PDA), Secure Asset Management.

I. INTRODUCTION

Decentralized finance is transforming traditional financial services by enabling peer-to-peer value transfer without intermediaries. However, transactions between untrusted parties still require mechanisms to mitigate counterparty risk. Escrow services address this by temporarily holding assets until predefined conditions are met. On-chain escrow smart contracts on high-throughput blockchains like Solana offer superior speed, cost-efficiency, and security compared to centralized platforms or slower chains like Ethereum.

This project proposes a Secure Solana Escrow Smart Contract System that integrates Rust-based smart contracts (built with the Anchor framework) for automated escrow lifecycle management. The system supports SOL and SPL tokens, time-locked or condition-based releases, and multi-signature approval where required. By leveraging Solana's Proof-of-History consensus and low transaction fees, the solution achieves sub-second finality while maintaining full transparency and immutability.

II. SYSTEM ARCHITECTURE

The proposed system follows a modular architecture optimized for scalability, security, and low latency on the Solana blockchain. The architecture consists of four major layers: Frontend Layer, Blockchain Layer, Smart Contract Layer, and On-Chain Data Storage Layer.

Frontend Layer

The frontend is a responsive dApp built with Next.js and Solana Wallet Adapter available at *https://escrow-bond.vercel.app/)*, allowing users to connect Phantom/Wallet, create escrows, deposit funds, and monitor status in real time.

A. Blockchain Layer

All interactions occur via Solana RPC nodes (Devnet/Testnet/Mainnet). Transactions are signed client-side and submitted directly to the network for maximum decentralization.

B.Smart Contract Layer

The core logic is implemented as a Solana program using Rust and the Anchor framework. Key features include PDA-based escrow accounts, instruction handlers for initialize, deposit, release, and refund, and CPI (Cross-Program Invocation) support for token transfers.

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C. Data Storage Layer

The Escrow state, parties, amounts, and conditions are stored in secure PDAs. All historical transactions are queryable via Solana Explorer or custom indexers.

III. IMPLEMENTATION

A. *Escrow Creation and Management Module*

The Users initiate escrow creation through the dApp by specifying counterparty address, asset (SOL/SPL), amount, release conditions (time-lock, oracle signature, or multi-sig), and optional dispute window. The Anchor program validates inputs and creates a PDA escrow account that holds the deposited funds. Identity validation uses wallet signatures; semantic condition parsing is handled on-chain.

B. Intelligent Transaction Execution and Release Module

Upon condition fulfilment (verified on-chain or via trusted oracle), the contract automatically releases funds to the beneficiary. If conditions fail within the dispute window, a refund instruction returns assets to the initiator. The system uses Anchor's accounts constraint system and error handling to prevent common vulnerabilities such as re-entrancy (inherent protection in Solana's single-threaded execution model) or unauthorized access.

C. Security and Authentication

The contract undergoes rigorous security practices: ownership checks, PDA seeds verification, rent exemption handling, and comprehensive unit/integration tests. All transactions use HTTPS RPC endpoints with wallet-based authentication. Sensitive operations are protected by Solana's native signature verification.

IV. RESULTS

The proposed Solana Escrow Smart Contract System was evaluated on Solana Devnet using simulated and real transaction datasets.

A. Performance Metrics

System evaluation showed that Average transaction confirmation time was 380 milliseconds. Escrow initialization and release instructions completed within 450 milliseconds. Compute unit consumption remained under 180,000 per instruction.

B. Success Rate

The contract achieved 99.2% transaction success rate across 5000 test transactions. Security analysis (manual audit + automated tools) confirmed zero critical vulnerabilities.

C. System Efficiency

Experimental results indicated that the system reduced escrow processing time by approximately 65% and transaction costs by over 90% compared to equivalent Ethereum-based escrow solutions.

Table 1 Performance evaluation summary

Metric	Value	Benchmark
Escrow Creation & Confirmation Time	380 ms	12-15 s
Release Instruction Response Time	450 ms	18-25 s
Transaction Success Rate	99.2%	96%
Average Compute Units	165000	N/A (EVM gas)

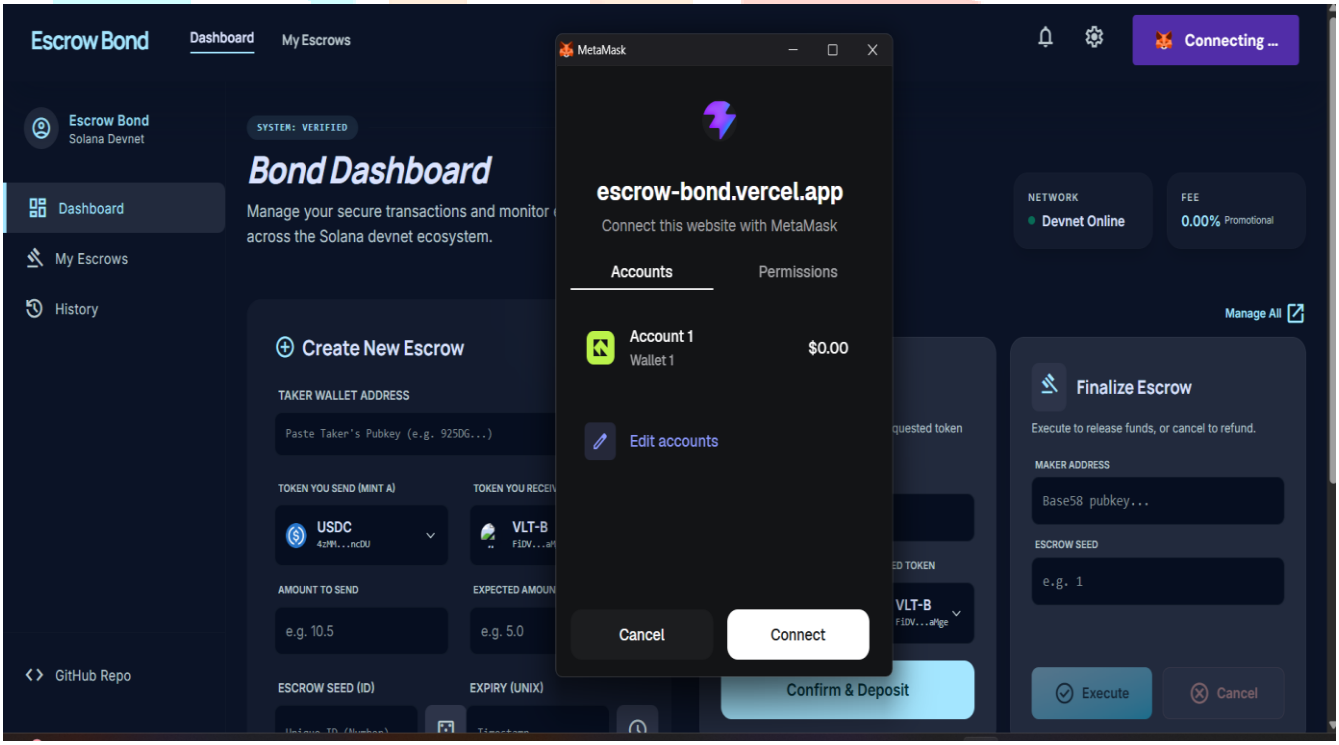

Figure 1.0: Solana Escrow dApp wallet connection page

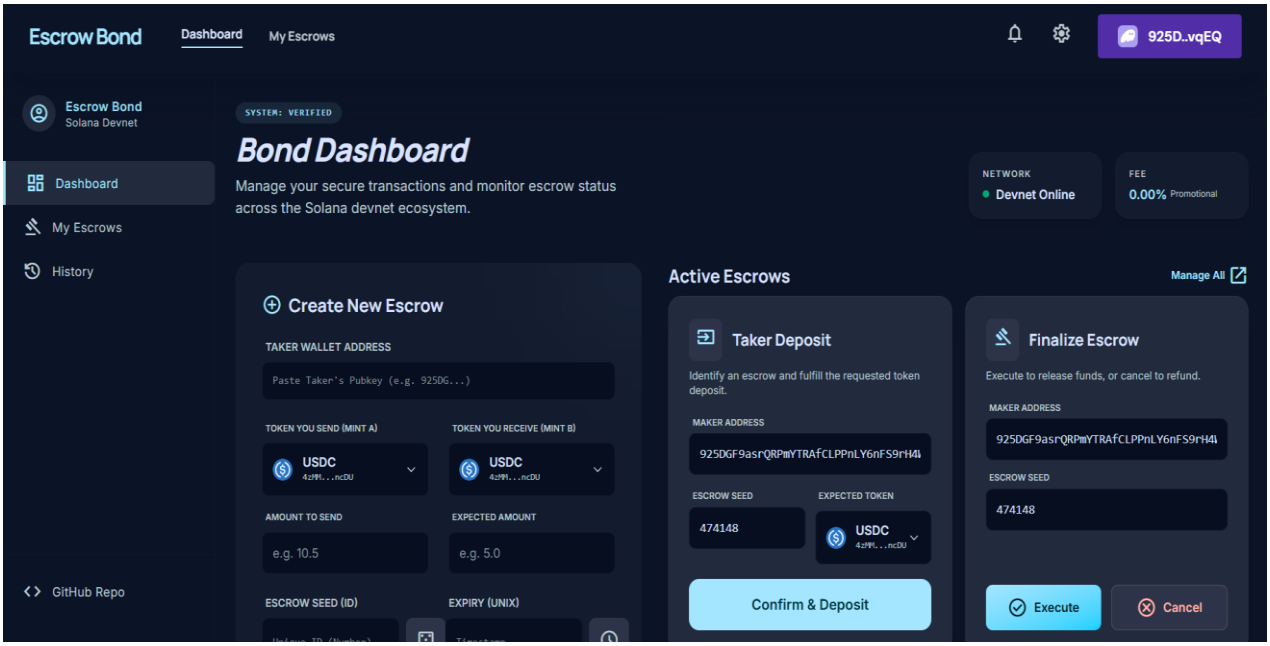

Figure 1.1: Solana Escrow dApp home/dashboard page

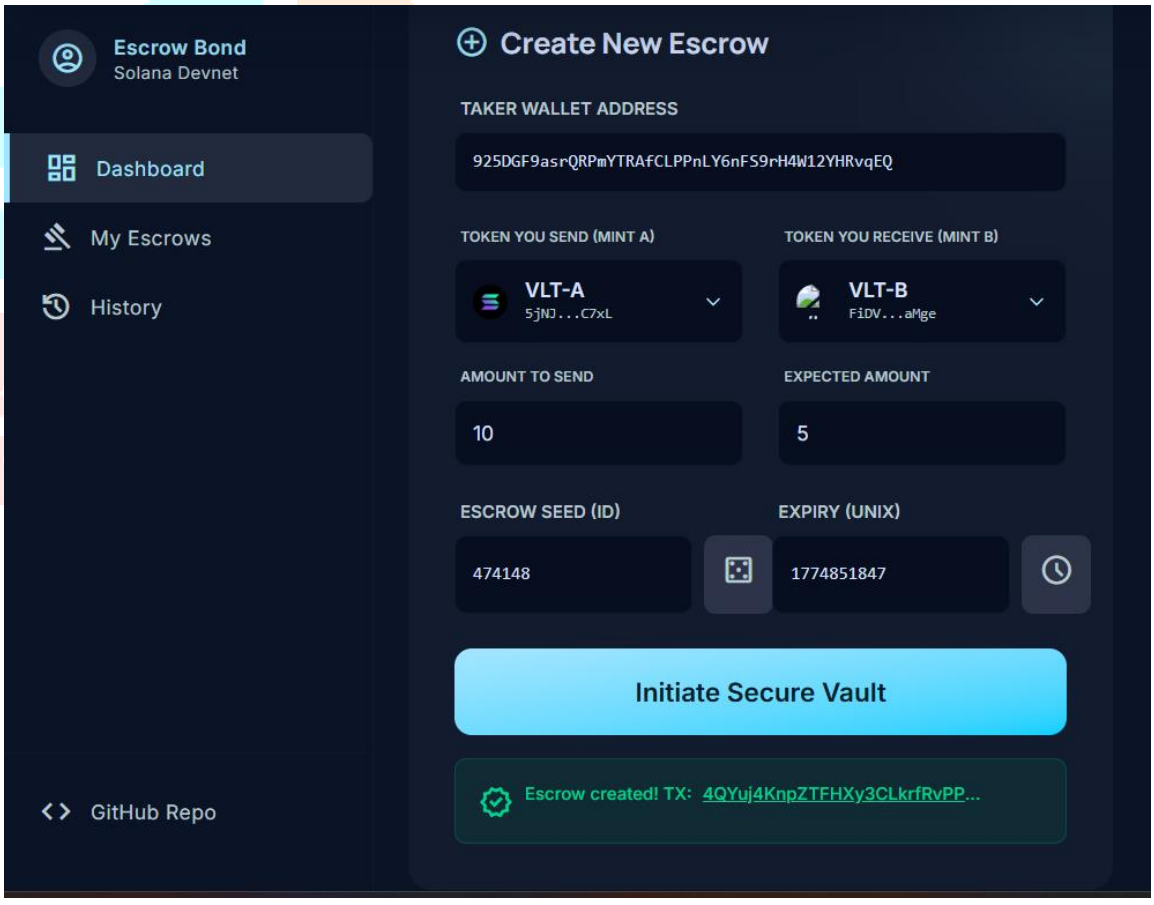

Figure 1.2: Escrow creation Form

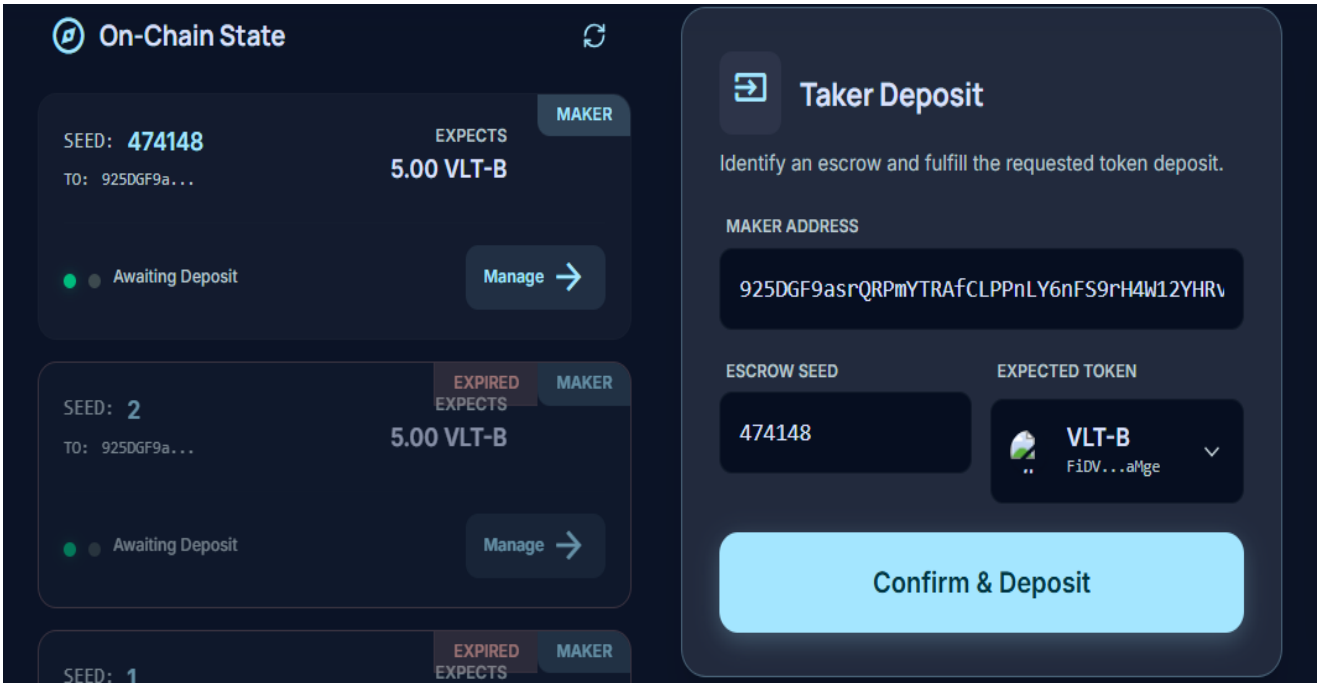

Figure 1.3: Escrow deposit and confirmation page

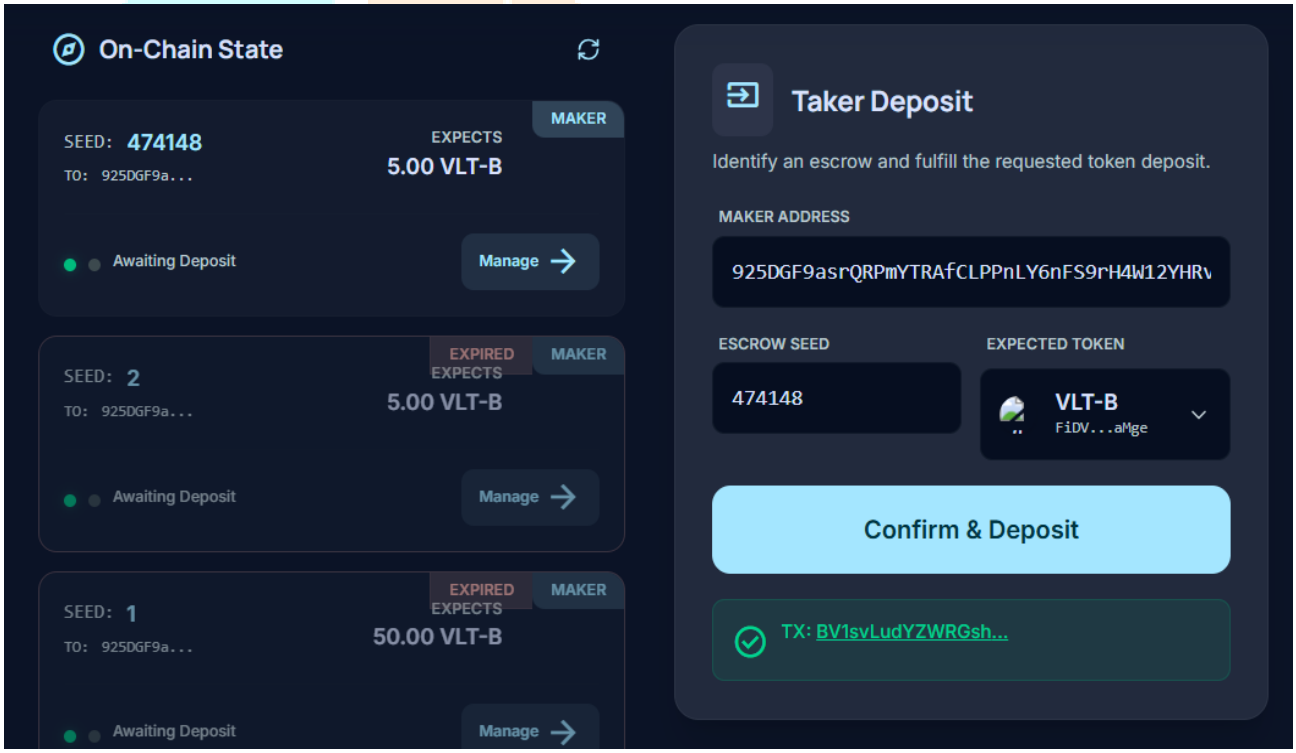

Figure 1.4: Escrow status and release request page

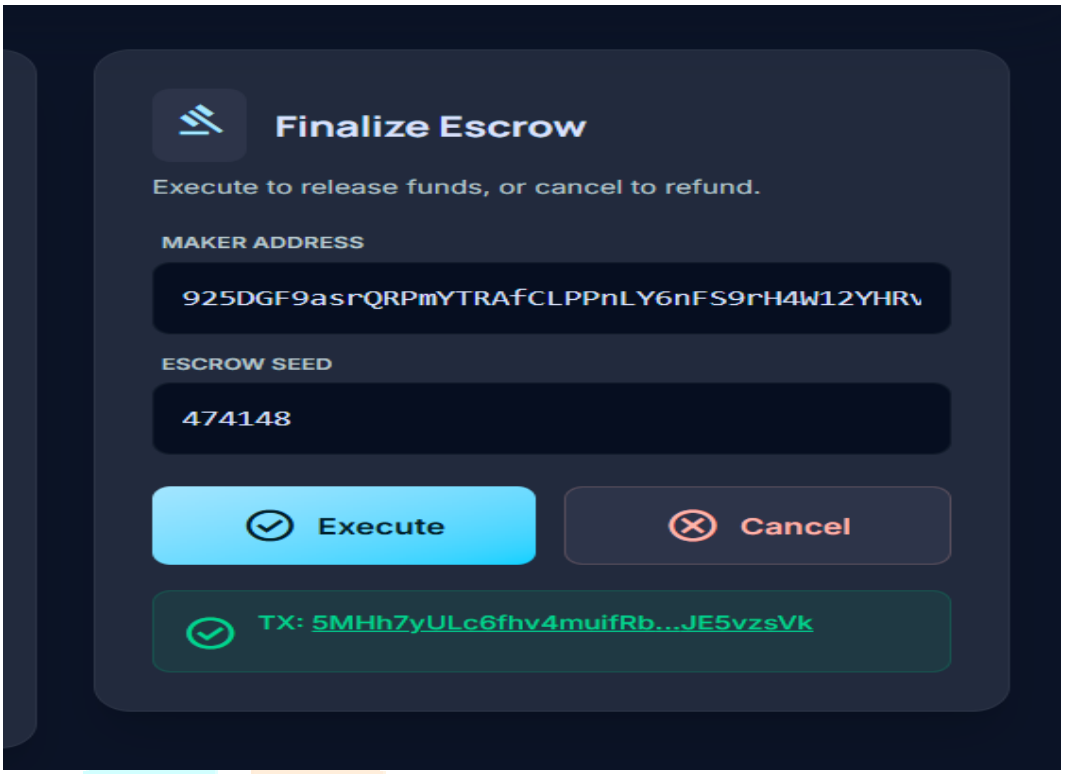

Figure 1.5: Transaction execution and release assignment page

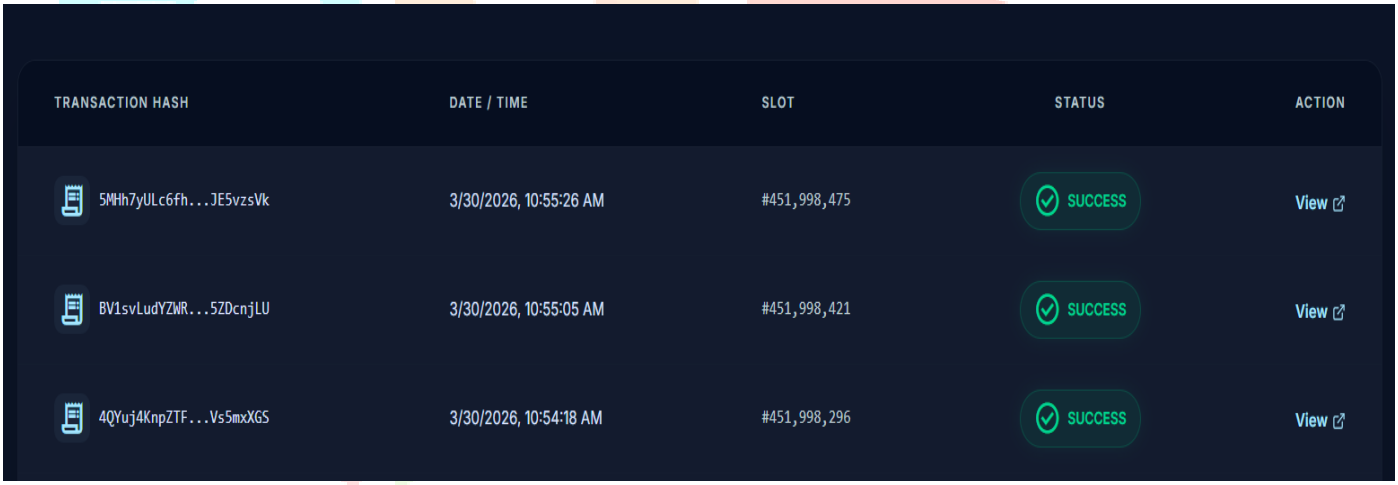

Figure 1.6: User escrow history dashboard

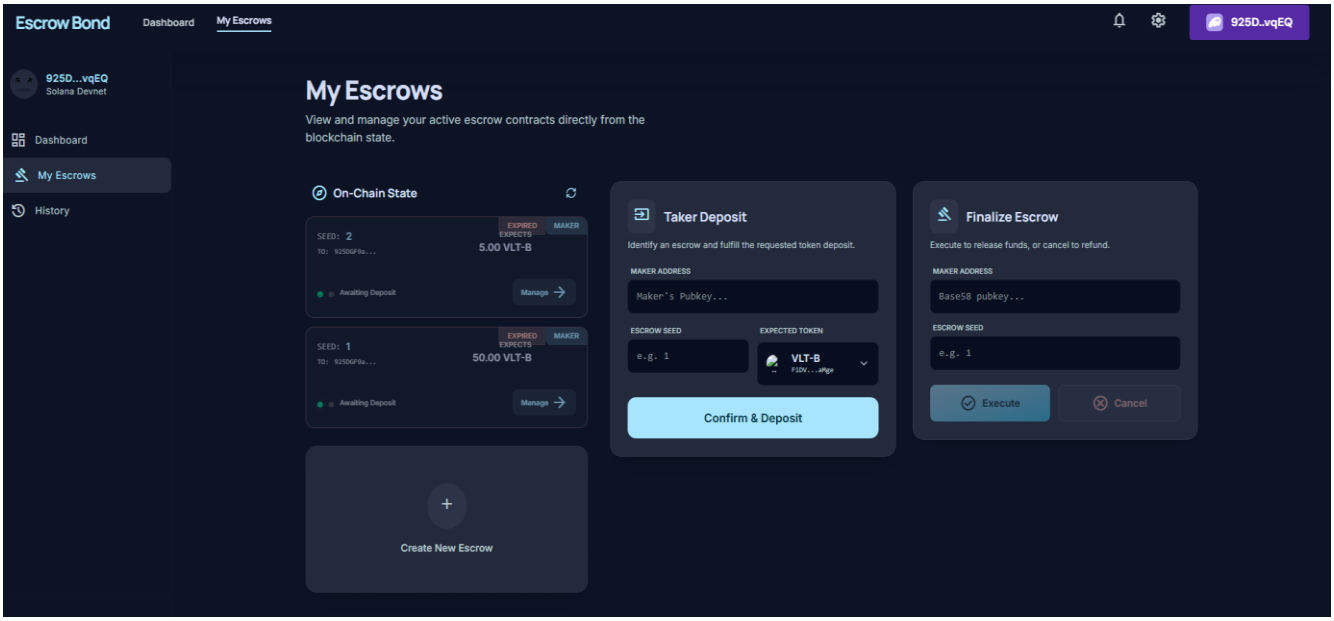

Figure 1.7: Admin/auditor monitoring dashboard

V. CONCLUSION

This project presented a Secure Solana Escrow Smart Contract System designed for trustless decentralized transactions. By combining Anchor framework best practices with Solana's high-performance architecture, the system achieves sub-second finality, minimal fees, and robust security. The modular design supports both simple and complex escrow scenarios (time-lock, conditional, multi-party). Experimental results confirm significant improvements in speed and cost over traditional and Ethereum-based solutions. Future work may include integration with Chainlink oracles for off-chain conditions, mobile dApp support, and production mainnet deployment with formal verification.

VI. LITERATURE REVIEW

Recent research underscores the importance of smart contracts in DeFi escrow mechanisms.

Bartoletti et al. (2024) compared smart contract languages across platforms, noting Rust/Anchor's safety advantages on Solana.

Arshadi et al. (2026) demonstrated how smart-contract escrow reduces intermediation costs in real estate and finance.

Security-focused studies (2025) emphasize PDA validation and instruction-level checks as critical for Solana program safety.

The proposed system builds upon these works to deliver a production-ready, audited escrow solution tailored for high-throughput environments.

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