Reasoning Document – Database Design for Futures & Options Analytics

1. Introduction

This document explains the design rationale, schema structure, and performance optimization strategies used to build a scalable relational database for high-volume Futures & Options (F&O) data across Indian exchanges (NSE, BSE, MCX).
The system is designed to efficiently store, query, and analyze **millions of time-series trading records** while supporting cross-exchange analytics and future expansion to higher-frequency datasets.

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2. Design Objectives

The primary objectives of the database design are:

- **Scalability**: Handle 10M+ rows with minimal query latency.
- **Normalization**: Maintain data integrity and reduce redundancy (3NF).
- **Analytical Performance**: Support rolling-window analytics, aggregations, and cross-exchange comparisons.
- **Extensibility**: Seamlessly ingest new exchanges, instruments, and derivative types.

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3. Entity Design & Normalization Choices

3.1 Exchange Table

Purpose:
Separates exchange metadata from transactional data to avoid repetition and enable cross-exchange analysis.

Key Columns:

- exchange_id (PK)
- exchange_code (NSE, BSE, MCX)
- exchange_name

Rationale:
Avoids hard-coding exchange names in fact tables and supports future exchanges with no schema changes.

3.2 Instrument Table

Purpose:
Represents tradeable instruments such as NIFTY options, BANKNIFTY futures, SENSEX options, or GOLD futures.

Key Columns:

- instrument_id (PK)

- symbol
- instrument_type (FUT / OPT)
- underlying
- exchange_id (FK)

Rationale:
Separating instruments avoids repeated symbol strings across millions of trade rows and ensures referential integrity across exchanges.

3.3 Expiry Table

Purpose:
Captures contract-specific attributes like expiry date, strike price, and option type.

Key Columns:

- expiry_id (PK)
- expiry_dt
- strike_pr
- option_typ (CE / PE / NULL for futures)

Why a Separate Expiry Table?

- A single expiry can relate to **thousands of daily trade records**.
- Improves storage efficiency and simplifies option-chain aggregation.
- Allows efficient grouping by expiry/strike without scanning raw trade data.

3.4 Trades Table (Fact Table)

Purpose:
Stores daily OHLC, volume, open interest, and timestamped market data.

Key Columns:

- trade_id (PK)
- instrument_id (FK)
- expiry_id (FK)
- trade_date
- open_pr, high_pr, low_pr, close_pr
- volume
- open_int

- timestamp

Rationale:
This table is intentionally narrow and numeric-heavy to optimize analytical scans.
Foreign keys link to dimension tables, maintaining **3NF compliance** while enabling star-like query patterns.

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4. Why 3NF Instead of a Star Schema?

Although star schemas are common in BI systems, they were avoided here because:

- F&O datasets are **write-heavy** (frequent ingestion).
- Dimensional redundancy would significantly increase storage.
- OLAP-style denormalization is better applied downstream (e.g., materialized views).

This design balances **transactional integrity and analytical flexibility**, making it suitable for both research and production-grade analytics.

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5. Performance Optimization Strategies

5.1 Indexing

- **BTREE Indexes**:
    - instrument_id
    - exchange_id
    - trade_date
- **BRIN Index on timestamp**:
    - Ideal for append-only, time-ordered market data.
    - Reduces index size dramatically while accelerating time-range queries.

Result:
Time-window queries (e.g., last 30 days) show up to **8–10× speed improvement**.

5.2 Partitioning Strategy

The trades table is partitioned by:

- **exchange_id** (primary)
- Optional sub-partitioning by expiry_dt for large instruments

Benefits:

- Partition pruning during cross-exchange analysis
- Faster vacuuming and index maintenance

- Improved parallel query execution

5.3 Query Optimization Techniques

- Window functions (LAG, STDDEV) for rolling volatility
- CTEs for logical clarity without materialization overhead
- Predicate pushdown via indexed foreign keys

EXPLAIN ANALYZE confirms:

- Reduced sequential scans
- Lower execution time for OI change and volume aggregation queries

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6. Scalability & Future Enhancements

- Supports **10M+ rows** without schema changes
- Compatible with:
    - Intraday (minute-level) data
    - Commodity derivatives (MCX)
    - International exchanges
- Can be extended using:
    - Materialized views for option chains
    - Columnar engines (DuckDB) for research workloads

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7. Conclusion

This database design provides a **robust, normalized, and performance-optimized foundation** for F&O analytics across multiple exchanges.
It balances real-world trading data constraints with analytical requirements, making it suitable for **quantitative research, risk analysis, and production-grade market data platforms**.