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Executive Summary

The **Risk Model Methodology Specification** outlines the framework and computational approach used for margin calculation and portfolio risk assessment. The model is designed to measure potential financial exposure by incorporating various risk factors, statistical correlations, and scenario-based stress testing.

The methodology leverages **historical market data, volatility estimates, and correlation structures** to ensure accurate and dynamic margin calculations. The key components of the model include:

- **Data Inputs** – The model relies on market data, trade attributes, and historical price movements to estimate potential future risks.
- **Risk Factors** – A set of predefined risk factors, including market fluctuations, price volatilities, and interest rate changes, drive portfolio risk assessment.
- **Correlation & Dependencies** – The model incorporates correlation matrices to assess interdependencies between assets, ensuring accurate diversification effects.
- **Conditional Value at Risk (CVaR) Calculation** – A tail-risk measure that estimates potential losses beyond a given confidence level, enhancing risk sensitivity.
- **Stress Scenarios & Extreme Market Conditions** – The model incorporates stress testing to simulate extreme market shocks, ensuring resilience against high-volatility events. This allows the system to evaluate worst-case scenarios and their impact on margin requirements.

By integrating these elements, the model ensures a **comprehensive and resilient margin framework**, helping market participants manage financial exposure efficiently. This document serves as a technical foundation for risk managers, regulators, and system developers in understanding the model's design and implementation.

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1. Overview & Introduction

1.1 Purpose

A clearing house plays a crucial role in clearing and settling trades such as FX derivatives, NDFs, NDOs, and FX options for its members. To protect both the central counterparty (CCP) and its members from potential losses due to a defaulting party, it requires a deposit—known as margin—from both counterparties as security.

To determine this margin, the clearing house must develop a robust risk model capable of accurately calculating the initial margin for each trade.

1.2 Scope

The model aims to determine the initial margin for the entire portfolio of members and clients. It will cover FX deliverables, NDFs, NDOs, and FX options while accounting for key risk factors such as FX spot movements, interest rates, and Greek sensitivities—including delta, gamma, theta, Vega, and rho—for non-linear instruments.
To ensure accurate margin calculations, the model will incorporate:

- Risk Methodology: Conditional Value at Risk (CVaR) at a 99% confidence level.
- Portfolio Adjustments: Correlation and netting concepts to optimize margin requirements.
- Additional Considerations: Market stress scenarios, Type II error considerations, and a 5% liquidity haircut to address market liquidity risks.

1.3 Intended Users

The model is designed for clients and its members to monitor portfolio risk, as well as allow clients or its members to recalculate the margin for new trades before they can be sent for clearing and settlement. Risk Manager and Portfolio manager can also use it for internal analysis purpose

1.4 Risk Model Overview

This model assesses the risk exposure of an FX derivatives portfolio by computing key risk sensitivities (Greeks), applying stress testing, and adjusting for correlations across different instruments, including FX options, NDFs, NDOs, and FX forwards. It calculates Delta, Gamma, Vega, Theta, and Rho for options using the Garman-Kohlhagen formula, while linear instruments are evaluated based on interest rate and FX spot changes. Stress testing involves predefined market shocks, capturing extreme but plausible scenarios, and correlation matrices are applied to adjust the stressed P&L, reflecting net exposure more accurately.

To ensure capital adequacy, the model employs Conditional Value at Risk (CVaR) at the 99% level to determine the Initial Margin (IM) requirement. Historical P&L data is sorted to compute 99% VaR and CVaR, setting IM as the absolute value of CVaR. This methodology ensures that risk exposure is quantified under both normal and stressed conditions, allowing for more effective risk management and regulatory compliance.

2.0 Datapoints

The Risk engine consist of four main components Data input, Risk exposures , Stress testing and Back testing.

2.1 Data input

There are three main data input required for our model Instrument data, risk factor, historical data. Some data will be pulled via api like Instrument or trade data which will come from external system. Greek values like, delta, vega, theta, gemma and rho will be calculated with respective portfolio, and historical data's like FX spot price will be called from internal or cloud database

2.1.1 Instrument data

Field Name	Definition
Trade ID	A unique identifier assigned to each trade for tracking and reference.
Trade Date	The date when the trade was executed between two counterparties.
Counterparty 1	The first party (bank or financial institution) involved in the trade.
Counterparty 2	The second party involved in the trade (can be another bank, client, or institution).
Instrument Type	The type of financial contract being traded, such as **FX deliverables, NDF (Non-Deliverable Forward), NDO (Non-Deliverable Option), or FX options**.
Notional Amount	The total value of the trade contract. It represents the principal amount on which the financial transaction is based.
Currency Pair	The two currencies being exchanged in the trade (e.g., USD/INR).
Settlement Date	The date on which the trade is scheduled to be completed, meaning funds are exchanged between counterparties.

Sample snippet:

Trade ID	Trade Date	Counterparty 1	Counterparty 2	Instrument Type	Notional Amount	Currency Pair	Settlement Date	
T123456	2025-03-18	Bank A	Bank B	NDF	10,000,000	USD/INR	2025-06-18	

2.1.2 Risk Factor dataset

In our Risk engine, there are both non-linear as well as linear instruments and risk factors are different linear and non-linear instruments, as seasonality is not present in linear assets like NDF and FX deliverables so we don't need to calculate Greek values for those instruments. But for non-linear instruments like FX options and NDO we need to calculate Greek values like Delta, Gemma, theta, Rho, Vega.

The Greeks derived from the Black-Scholes model have clear **interpretations**:

- **Delta (ΔΔ)**: Sensitivity of the option price to changes in the underlying asset price.
- **Gamma (ΓΓ)**: Sensitivity of Delta to changes in the underlying asset price.
- **Vega (νν)**: Sensitivity of the option price to changes in volatility.
- **Theta (ΘΘ)**: Sensitivity of the option price to the passage of time.
- **Rho (ρρ)**: Sensitivity of the option price to changes in interest rates.

2.1.3 Historical data

2.1.3.1 Market data

We will consider 10-years of historical market data, this data will be used in running the model, and performing backtesting and stress testing

Market Data Type	Description	Ex data
FX Spot Price	The real-time exchange rate of a currency pair.	USD/INR = 82.50
Volatility Data	Historical and implied volatility of FX pairs.	USD/INR Implied Volatility = 7%

2.1.3. 2 Scenario analysis

Scenario Type	Description	Ex data	How to Create It?
Historical Scenario	Uses real past events to analyse the impact on FX markets.	2008 Financial Crisis, Brexit, COVID-19 Shock	Extract historical FX data from these periods and apply it to the current portfolio.
Hypothetical Scenario	Creates a potential event that has not occurred but could impact FX rates	A major cyberattack on global banking networks disrupting FX transactions.	Adjust FX volatility, correlations, and liquidity assumptions based on expert judgment.

3.0 Risk Model Methodology

The portfolio consists of FX derivatives, including NDFs, FX options (Calls and Puts), NDOs, and FX forwards. Each instrument is characterized by notional amount, position, strike price, maturity, and volatility. The input for this model is already discussed in Data Input section. Model will perform various task such as Risk Factor calculations, creating market stressed and checking impact of these market stress on Risk factor of every instruments. Once the Risk factor is revalued under stress conditions, it will use correlation matrix to offset the loss.

3.1 Risk Factor

Risk factor plays a vital role in understanding how asset reacts to potential changes, Risk factors are different for different instruments for example, for non-linear instruments like FX options and NDO **Greek sensitivity** can define risk better and for linear instruments **interest rate and FX spot moments** are considered. In our model we will be using **the Garman-Kohlhagen formula** for Greek values**, it** is an extension of the Black-Scholes model that accounts for the fact that FX options involve two interest rates (one for each currency).

3.1.1 Delta value (Δ)

Delta measures the sensitivity of the option's price to a change in the price of the underlying asset. For FX options, Delta is typically expressed as the change in the option's value for a 1% change in the spot FX rate.

Formula :-For call

$$\Delta_{\text{Call}} = e^{-r_f T} N(d_1)$$

For option

$$\Delta_{\text{Put}} = -e^{-r_f T} N(-d_1)$$

Where

N'(d1) is the **probability density function**, specifically N(d1) where N is the cumulative that the options will expire in the money

$$d_1 = \frac{\ln(S/K) + (r_d - r_f + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

e−rfTe$_{-r_fT}$ is the **discount factor**

3.1.2 Gamma (Γ)

Gamma measures the rate of change of Delta with respect to changes in the underlying asset's price. It is a second-order derivative and is important for understanding the curvature of the option's price

$$\Gamma = \frac{e^{-r_f T} N'(d_1)}{S\sigma\sqrt{T}}$$

Where

e−rfTe−rfT is the **discount factor**

S: Spot FX rate (domestic currency per unit of foreign currency).

T: Time to maturity (in years).

σ: Volatility of the FX rate.

3.1.3 Vega (v)

Vega measures the sensitivity of the option price to changes in volatility. For a call option, Vega is calculated as

$$\nu = Se^{-r_f T}\sqrt{T}N'(d_1)$$

Where

e−rfTe−rfT is the **discount factor**

S: Spot FX rate (domestic currency per unit of foreign currency).

T: Time to maturity (in years).

N'(d1) is the **probability density function**, specifically N(d1) where N is the cumulative that the options will expire in the money

3.1.4 Theta (Θ)

Theta measures the sensitivity of the option's price to the passage of time. It is typically expressed as the change in the option's value for a one-day decrease in the time to maturity.

Formula for call option

$$\Theta_{\text{Call}} = -\frac{Se^{-r_f T} N'(d_1)\sigma}{2\sqrt{T}} + r_f S e^{-r_f T} N(d_1) - r_d K e^{-r_d T} N(d_2)$$

Formula for Put option

$$\Theta_{\text{Put}} = -\frac{Se^{-r_f T} N'(d_1)\sigma}{2\sqrt{T}} - r_f S e^{-r_f T} N(-d_1) + r_d K e^{-r_d T} N(-d_2)$$

e−rfTe−rfT is the **discount factor**

S: Spot FX rate (domestic currency per unit of foreign currency).

T: Time to maturity (in years).

N'(d1) is the **probability density function**, specifically N(d1) where N is the cumulative that the options will expire in the money

rdr_d: Domestic risk-free interest rate.

rfr_f: Foreign risk-free interest rate.

3.15 Rho (ρ)

Rho measures the sensitivity of the option's price to changes in the interest rate. It is expressed as the change in the option's value for a 1% change in the interest rate.

Formula for call

$$\rho_{\text{Call}} = KTe^{-r_d T} N(d_2)$$

Formula for put

$$\rho_{\text{Put}} = -KTe^{-r_d T} N(-d_2)$$

K: Strike price.

T: Time to maturity (in years).

3.2 Market Stress

Foreign exchange (FX) risk modelling involves estimating potential financial losses under **extreme but plausible** market conditions. Stress scenarios help financial institutions **test their exposure** to adverse market events and determine the **Initial Margin (IM)** required to cover potential losses. As we are only considering 9 currency in our model we would like to create an scenario which can help use validate risk factor.

2008 Crisis Stress Scenario Parameters

Currency Pair	**Shock Applied**	**Shock Type**	**Reasoning**
EUR/USD	-12% (1M)	Spot Depreciation	Lehman collapse triggered massive USD funding demand; ECB lagged Fed in rate cuts.
GBP/USD	-14% (1M)	Spot Depreciation	UK banking crisis (RBS, HBOS bailouts) and BoE rate cuts.
USD/JPY	-10% (1M)	Spot Appreciation (JPY↑)	JPY safe-haven demand as carry trades unwound.
AUD/USD	-21% (1M)	Spot Depreciation	Commodity price crash (iron ore -50%) and risk-off flows.
USD/CAD	+15% (1M)	Spot Appreciation (CAD↓)	Oil price collapse (WTI -75%) hurt commodity-linked CAD.
NZD/USD	-18% (1M)	Spot Depreciation	High-beta currency selloff; dairy export demand drop.
USD/CHF	+10% (1M)	Spot Appreciation (CHF↑)	CHF safe-haven flows despite USD strength (SNB intervention limits).
USD/SEK	+20% (1M)	Spot Appreciation (SEK↓)	EM-style selloff in Scandies; Riksbank emergency rate cuts.
USD/BRL	+30% (1M)	Spot Appreciation (BRL↓)	EM capital flight; Brazil's commodity exports crashed.

And to apply shocks for non- USD pair, we will apply shocks using their base USD shocks

3.2.1 Cross Pair formula

A **cross currency pair** is any currency pair **without USD as the base or quote currency**, e.g., **EUR/JPY, GBP/CHF**.

Since stress scenarios generally define shocks in terms of **USD pairs** (e.g., EUR/USD, USD/JPY), we need to **derive cross pairs** using those USD pairs.

For any cross currency pair **X/Y**, you can calculate the new stressed rate using the following formula:

$$\text{Stressed}(X/Y) = \frac{\text{Stressed}(X/USD)}{\text{Stressed}(Y/USD)}$$

💡 This formula works because:

$$\frac{\text{EUR}}{\text{JPY}} = \frac{\text{EUR}}{\text{USD}} \times \frac{\text{USD}}{\text{JPY}}$$

The model will perform P and L calculation under above stress condition, in order to check it's the Greek values.

3.3 Correlation

Before directly calculating **VaR and CVaR**, we need to understand how correlation between different instruments in our portfolio affects overall risk exposure.

Why Use Correlation?

- Not all FX instruments in the portfolio move independently.
- Some currency pairs have a **positive correlation** (move in the same direction), while others have a **negative correlation** (move in opposite directions).
- Incorporating correlation **reduces overall portfolio risk** because gains in one position may offset losses in another.

In order to implement correlation, we will use historical FX correlation currency pair value, we will pull this data from the API.

The model will use below formula to compute correlation to each and every instrument which are positively or negatively correlated.

The new P&L for each instrument after considering correlation is calculated as:

$$PnL_{adjusted} = PnL_{stress} + \sum(\rho_{ij} \times PnL_j)$$

where:

- PnLstressPnL_{stress}PnLstress = New P&L under stress without correlation

- ρij\rho_{ij}ρij = Correlation between instrument iii and instrument jjj
- PnLjPnL_jPnLj = P&L of the correlated instrument

3.4 Initial Margin using CVar

In financial risk management, **Value at Risk (VaR)** and **Conditional Value at Risk (CVaR)** (also known as **Expected Shortfall**) are key metrics used to measure the potential downside risk of a portfolio. These metrics are crucial in determining the required **Initial Margin (IM)** for trading derivatives, including **FX options, NDFs, and deliverable forwards**.

- **VaR (Value at Risk)**: Measures the worst expected loss at a given confidence level (e.g., 99%) over a specific time horizon.
- **CVaR (Conditional Value at Risk)**: Measures the **average loss** in the worst-case scenarios (i.e., beyond the VaR threshold). It is considered a more **conservative and stable** risk measure than VaR.

Since VaR only gives the **minimum expected loss in extreme cases**, it does not fully capture **tail risk**. Hence, **regulatory frameworks such as SIMM (Standard Initial Margin Model) and LCH's risk models** prefer **CVaR for Initial Margin calculations**

VaR provides a risk threshold but ignores **the magnitude of losses beyond that threshold**. Since Initial Margin is designed to cover extreme losses, CVaR is preferred because:

1. **Captures tail risk**: CVaR accounts for losses beyond the VaR threshold, making it a better predictor of potential extreme losses.
2. **Provides a more stable margin requirement**: Since CVaR is based on an average of worst-case losses, it is less volatile than VaR.
3. **Regulatory preference**: CVaR is increasingly used in margin models by clearinghouses like **LCH, CME, and ICE**.

Following are the steps how CVar model will run in our model.

Step 1: Compute Historical Profit and Loss (P&L) Distribution

- Collect the **daily P&L** of the portfolio over a given period (e.g., 100 days).
- Sort the losses from least to most severe.

Step 2: Compute 99% VaR

- Identify the **1st percentile (99% confidence level)** of the sorted loss distribution.
- This represents the worst expected loss **in 99 out of 100 cases**.

$$VaR_{99\%} = \text{Loss at 1st percentile}$$

VaR99%=Loss at 1st percentileVaR_{99\%} = \text{Loss at 1st percentile}VaR99%
=Loss at 1st percentile

Step 3: Compute 99% CVaR (Expected Shortfall)

- Compute the **average loss** beyond the **VaR threshold** (i.e., the average of the worst 1% of losses).

Step 4: Compute Initial Margin (IM)

- **Initial Margin is set as the absolute value of CVaR (99%)** to ensure sufficient capital is available to cover extreme losses.

$$IM = |CVaR99\%|$$

4.0 Limitation

- The model is designed for FX derivatives and may not be easily adaptable to other asset classes without significant modifications.
- The model relies heavily on accurate and up-to-date data, including market data, historical data, and risk factor datasets. Errors in these datasets could lead to incorrect margin calculations.
- While stress testing is incorporated, the predefined market shocks and hypothetical scenarios may not fully capture the complexity or unpredictability of real-world market events.
- The correlation matrix applied to adjust stressed P&L assumes static relationships between instruments, which may not reflect sudden shifts or breakdowns in correlations during crises.
- The model is focus on specific instruments (eg: FX options, NDF , NDO) and may not be generalise well to portfolios with broader range of derivatives