EURORISK SYSTEMS LTD.

Risk Engine

Analytical Software System for Institutions and Companies in the Financial Industry

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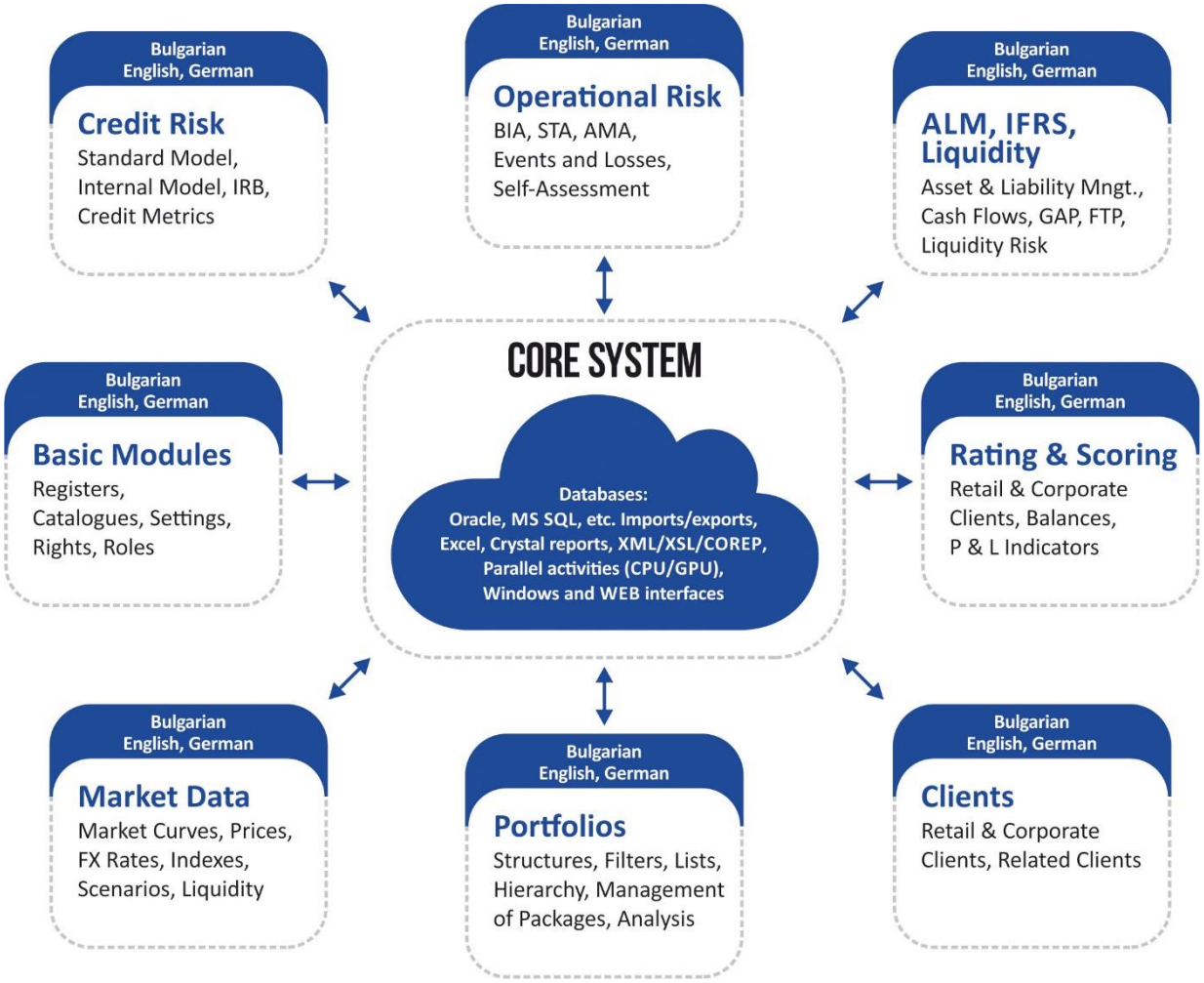
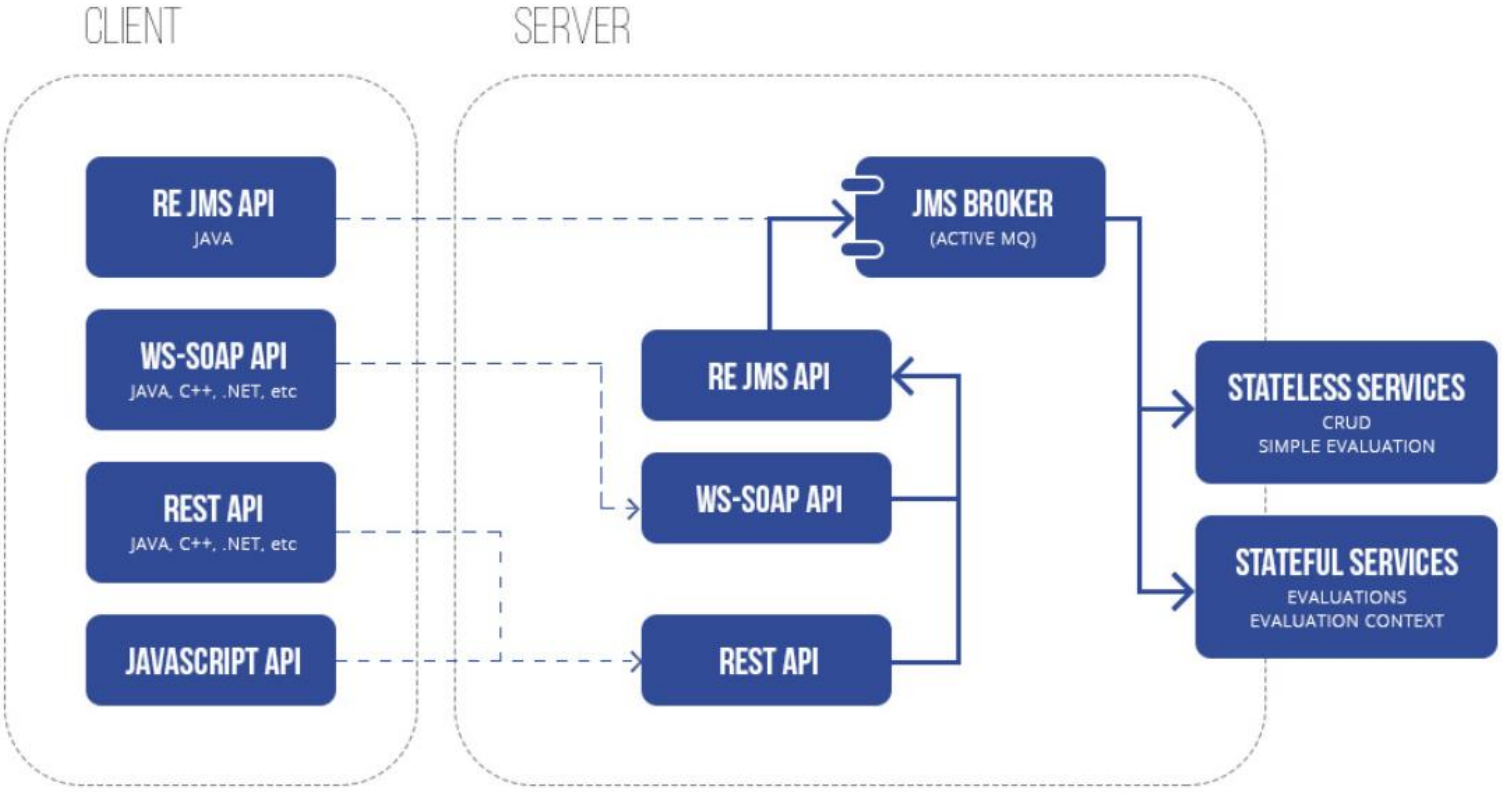
Risk Engine Modules are based on models and rules



Risk Engine Architecture



About & Features

About Risk Engine

Risk Engine (RE) is a software platform for portfolio management, specially designed for risk management in the financial industry. It is intended for medium-sized and large enterprises (for ex. banks, insurance companies, funds, etc.) with exposures to financial market risks or observable risk bearing market factors. To recognize, analyze and quantify risk, RE employs modern paradigms, such as programming, artificial intelligence, neural networks, statistics and simulations. The platform applies Service Oriented Architecture (SOA), aiming to support all configurations of client-server applications. User access to the server is enabled solely via the APIs, which are kept in compliance with the industry standards, providing easy usage to cross-platform clients.

The self-explanatory user interface, along with the efficient calculation methods of Risk Engine, enable:

- Management of financial objects, for ex. market data (quotes, indices, rates, etc.), transactions, positions, instruments (incl. insurances), portfolios and scenarios
- Sophisticated simulations of future behaviors of market factors (e.g. indices, yield curves, FX etc.), client behaviors (ALM module) and investments at different stress levels
- Easy reporting via standard reporters, advanced reporting and OLAP presentation tools

The architecture of Risk Engine's system enables an easy integration to existing systems, as well as stand-alone operations through data exchange via imports and exports. All system modules are highly flexible and can easily be modified to provide the best solution for specific business requirements.

Risk Engine operates in the following manner:

- Market data import –via its API and/or standard importer
- Data processing via analytical modules – a set of analysis, data subsets and the like is defined according to the required evaluation via the API system
- Reporting of results into result tables of the data base, or via the supported reporting engines

Many companies have already given us their trust and discovered the benefits of Risk Engine. Isn't it time for you to do the same?

Risk Engine Features

Risk Engine is a system that enables measurements of market risks and analysis of investments. Its main features are:

- Precise modelling of the market – prices, indices, yields, spreads, scenarios, statistics, yield and credit spread curve bootstrapping, normalization and interpolation, etc.
- Precise modelling of investments – cashflow generation, conventions, optionality, etc.
- Over 60 fixed financial instruments
- Advanced stress testing on all types of factors, categorized into groups or on a per-factor basis
- Usage of multiple models to represent positions: internal model, Delta model, Delta-Gamma model, user-defined by rules, data-driven and predictive models
- Advanced risk measurement methods based on Monte Carlo simulation
- Designed to be easily integrated into other applications, but can operate by itself, as well
- High performance: ad hoc concurrent calculations. A typical simulation includes approximately 1000 positions. In some cases, this number can increase to 100.000 positions. Horizontal scaling of evaluations
- Easy integration by enabling access to the system only via the respective API or GUI. Supported APIs – Messaging (JMS), REST, WS-SOAP; Browser or Tablet compatible GUI. Uses HTML/CSS/JavaScript only, no applets, flash etc.

Risk Engine covers the following financial instruments:

- Equities (e.g. shares, funds, commodities, index-linked cash, private equities)
- Capital instruments with optionally embedded spread risk (e.g. bonds: straight, floater, inflation; money markets: bullet, capitalization, rollover; loans: annuity, regular (fix, float); deposits: savings, user-defined; swaps: FX, CC, IR (fix/fix, fix/float, float/float); UVG; other: cash accounts, CDS, credit lines, FRA, FX outrights; user-defined by rule-based instruments)
- Derivatives (e.g. options on bond future, commodities, FX, IR, stocks, stock indices; swaptions; cap/floors; futures on bond, commodity, FX, IR, stock indices; CFD on instrument, stock indices; user-defined by rule-based instruments)
- Modelling and pricing of structured products and exotics through rule-based instruments
- Modelling and pricing of structured products and exotics using the multi-factor approach

Risk Engine Modules

The list of Risk Engine's modules covers but is not limited to the following modules:

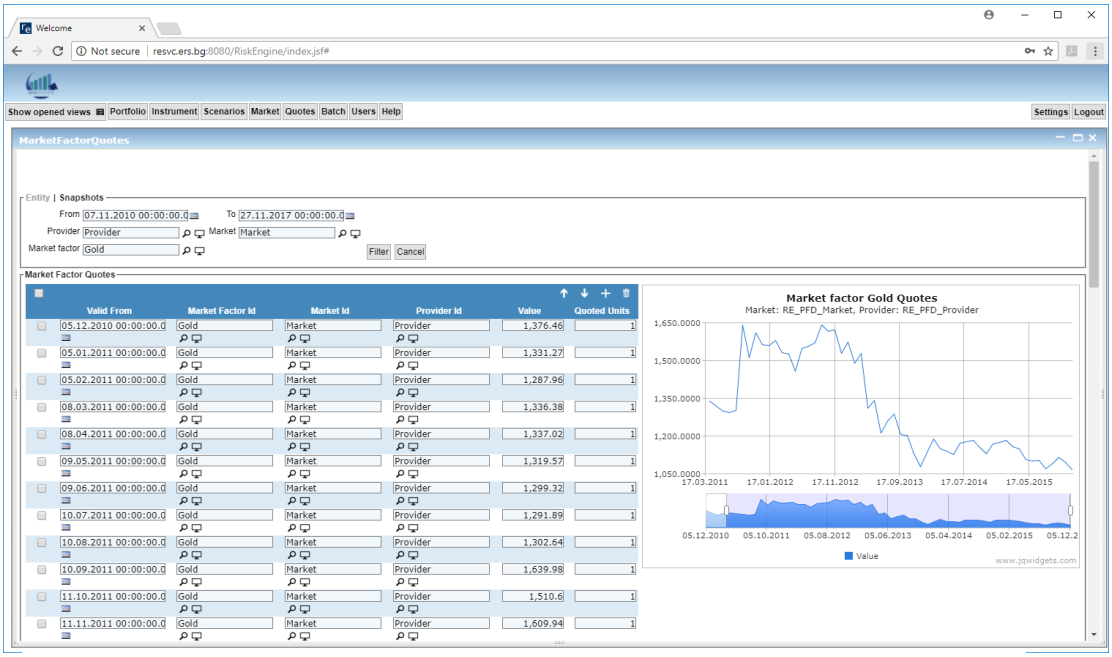
№	Modules	Functionality
1	System Administration User rights	Has lists of instruments, positions, filters, portfolios, scenarios, reports, etc. Registration of users, roles and rights to access the system Settings, currencies, countries, cities, markets, financial calendar
2	Asset Allocation Portfolio structuring	Supports multi-level portfolio (re)structuring based on calculation Supports multi-level portfolio (re)structuring based on calculation Results and position properties. Performs allocation of positions, for ex. by currencies and then by maturity bands. Static and dynamic portfolio structures are possible.
3	Market Environment Scenarios Stress Testing	Provides means to manage the market environment and historical time series used by all modules: • Instrument prices and dividends • Yield curve, Credit spread curve, Life curve • FX rate, Stock index, IB rate, Rating spread • Implied volatility • Bond future basket • Multiple markets and providers Provides means to define different strategies for scenario changes in the market environment to compose real world scenarios, such as Crisis, Growth, Market Shock, Issuer Defaults, Refinancing Costs, etc., realized by: • Market scenarios: FX scenario, Stock index scenario, IR/Yield curve scenario • Cash-flow and liquidity scenario
4	Portfolio Evaluations Expected Loss CVA/DVA	All evaluations are performed with regards to a selected market scenario. Furthermore, results are aggregated on every level of the portfolio structure. When multiple scenarios are selected, scenario results can be compared on all levels. The following results are calculated: • Market and Theoretical values, Profit /Loss, Return • Basic sensitivities – durations, Greeks, historical and implied volatilities, base point value, key rate values, etc. • Hedging by BPV and Beta • Scenario projection – portfolio theoretical value development over time, based on selected market scenario • Multiple market scenarios applicable Expected Loss is calculated via spread curves assigned to the respective issuers or via probability matrix based on issuer ratings. With derivatives, Credit /Deposit Value Adjustment (CVA / DVA) is provided.
5	Portfolio Optimization	Performs optimization of risk and return and represents proposals for portfolio restructuring in the presence of different scenarios. The optimization is performed within user defined restrictions, representing the portfolio owner's preferences, e.g. Investments in EUR > 30% and investments in USD < 40%. The following functions are available: • Markowitz optimization, including non-linear portfolios • Efficient frontier calculation • Portfolio optimization proposals • Historical data sets applicable • Portfolio restrictions applicable • Market, volatility and value scenarios applicable
6	Asset Liability Analysis	Provides means to present the future cash flow disposition and to detect any gaps, investment efficiencies in the presence of different market scenarios. Also, in the presence of cash flow scenarios, different future behavioral changes (Growth, Defaults of large customers, deposits increase, etc.) may be tested in order to optimize the asset and liability management. User defined attributes can be defined for positions, instruments and portfolios. The following functions are available: • Cash-flow disposition • Interest income / Fund transfer pricing • Liquidity VaR and Gap analysis • Multiple market scenarios applicable
7	Value at Risk (VaR)	Value at Risk (VaR) calculation on all levels of the portfolio structure while taking into account the current market scenario. When multiple scenarios are selected, the results can be compared. • Multi-factor Monte-Carlo based VaR calculation, VaR types: Total, FX, IR, SI, Share, Mixed, Marginal, Incremental, Spread, Historic • Market VaR projection over time • VaR break down by asset classes • VaR back testing • Multiple market scenarios applicable
8	Performance Calculation	Performance of positions and portfolios is calculated for a historical period, incl. transactions. The performance is separated into realized, non-realized and FX-effects, which are aggregated along the sub-portfolio hierarchy. Performance can also be tracked against a multi-level benchmark. The following components are included into the calculation: • Market and Paid Prices at the beginning and at the end of the historical period • Accrued interests at the beginning and at the end of the historical period • Capital and interest rate in+/out payments within the historical period • Fees and Taxes within the historical period • Profit / Loss calculation • Benchmark tracking
9	Limit and Notification	Management of Limits, Compliances and Alerts, defined by a specialized restriction language, which allows free formulation of limits or easy description of financial law documents, for ex. capital investment low, UCITS IV, etc. Designed to produce real time alerts for pre-trade checks. Management of Notification Events: messages, SMS, mails included
10	Service API	RE functions are also accessible via its service APIs, which makes the integration with other applications very simple. Any client can include the desired functions to its own workflow or create an application mixing services of other providers transparently. All market data, positions, portfolios, etc. are accessible and editable if the accompanying user rights allow it. The services support multiple users and each user can use its own data base (within the list of supported DB types). The installation supports vertical and horizontal scaling and can be installed remotely or on premise.
11	Swiss Solvency Test (SST)	Flexible definition of Swiss Solvency Test (SST) with standard and custom scenarios. Special mapping of functions between SST recognized risk factors and actual risk factors.
12	Solvency II	Solvency II market risk modules and aggregations with full internal model stresses.

Swiss Solvency Test (SST) Module in Risk Engine

The Swiss Solvency Test (SST) records the economic risk situation of insurance companies. It is a principle-based and risk-based audit tool that uses a total accounting approach. Insurance companies must assess all investments and obligations in a market-consistent manner. Subsequently, the possible changes in balance sheet items are to be modelled over the time horizon of one year. Based on this, the required capital must be determined.

In Risk Engine, the implementation/calculation of SST is a matter of configuration, which includes:

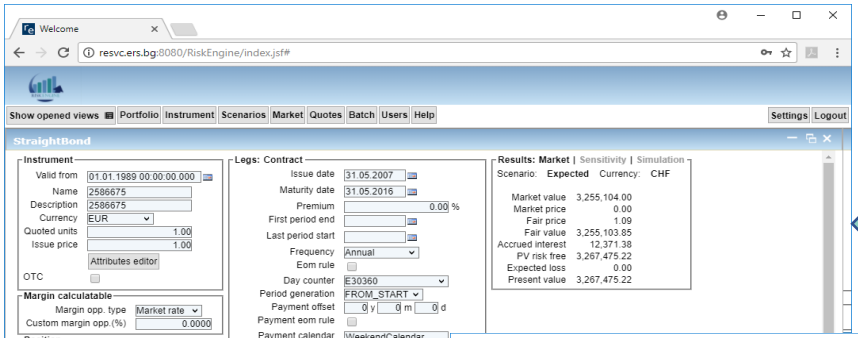
- Configuration of market factors that are part of the SST market universe
- Import of SST market universe quotes
- Configuration of RE market scenarios to describe the FINMA scenario cases – Quadranten, Pandemie, etc.
- Configuration of the RE factor dimension reduction to map the SST market factor universe to actual portfolio/system factors:



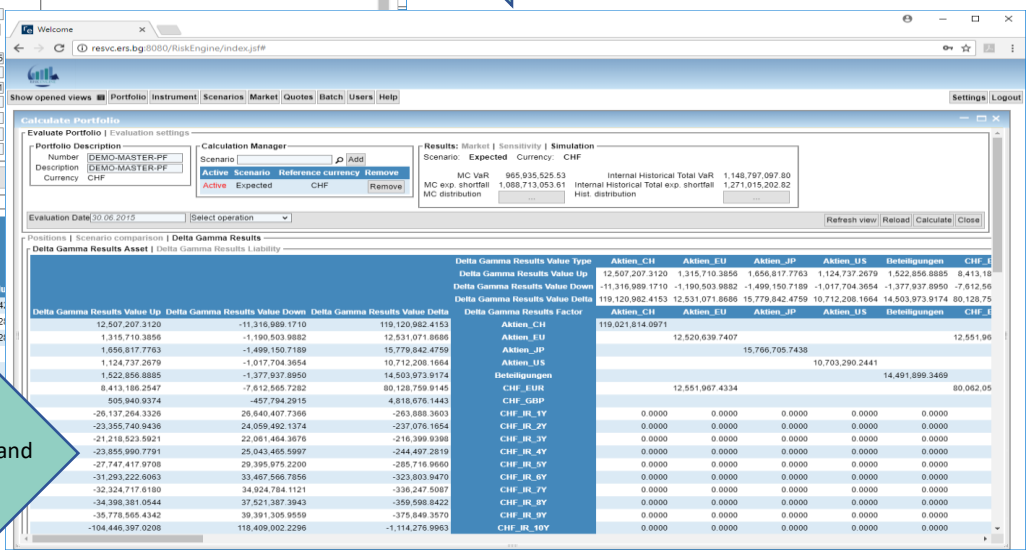
Market factor quotes for gold ordered in time. **Time series chart.**

  - The mapping can be derived from market data and can be user-defined, fixed, or both
  - If a data-driven model is used, instruments can be configured to track the FINMA market universe. In this case, dimension reduction configuration is not needed

- Portfolio calculation with SST parameters – Smith-Willson, confidence, correlation matrix correction, factor deflections, etc.



Delta/Gamma results on position level

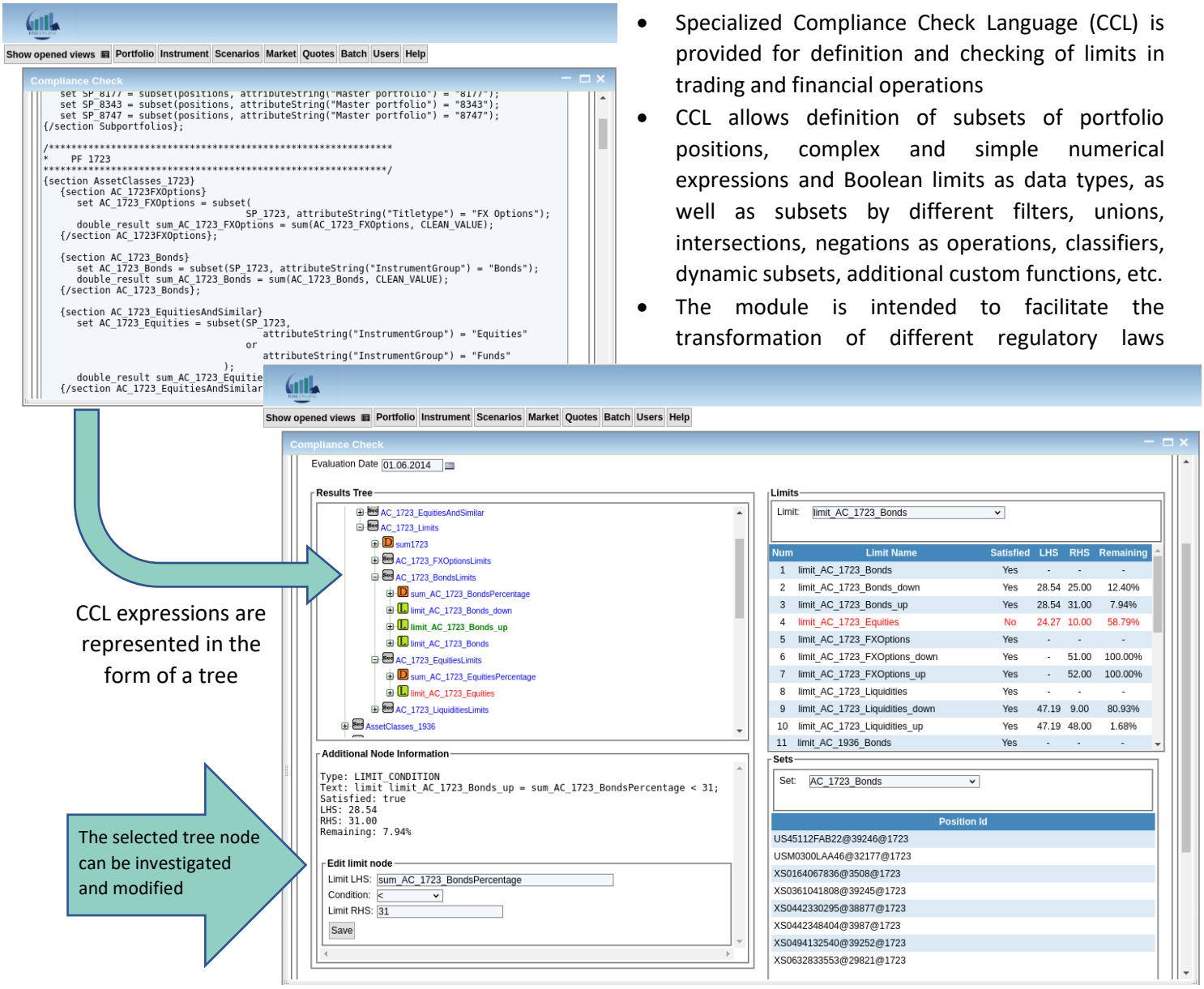


Delta/Gamma results on asset and risk factor level

Compliance Check Module in Risk Engine

The Compliance Check module defines and evaluates restriction rules – such as limits and simple or structured conditions – within the RE system, that apply to specified portfolios and their subsets. The goal is to identify violations, produce warnings and include them into reports. Depending on the portfolio, objects of rule sets represent:

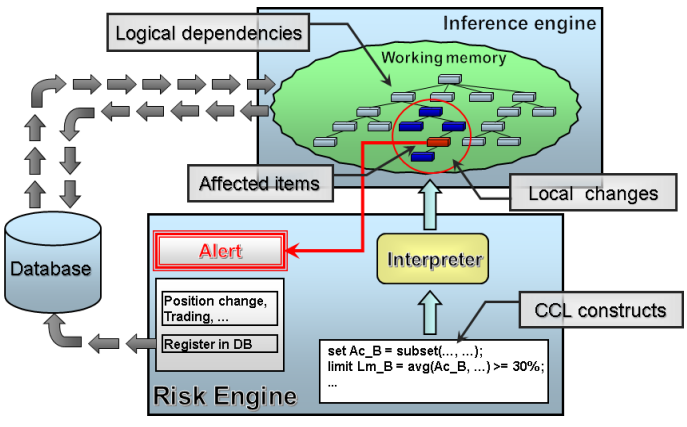
- Laws, regulatory rule sets (e.g. FINMA, SBV, Investment Fund Act, etc.)
- General or specific rule sets



- Specialized Compliance Check Language (CCL) is provided for definition and checking of limits in trading and financial operations
- CCL allows definition of subsets of portfolio positions, complex and simple numerical expressions and Boolean limits as data types, as well as subsets by different filters, unions, intersections, negations as operations, classifiers, dynamic subsets, additional custom functions, etc.
- The module is intended to facilitate the transformation of different regulatory laws

- The alert system underlines not only the violated limits but also satisfied limits that are close to violation
- Graphical user interface is provided that facilitates definition and changes of language elements, by using of combo boxes, text fields, etc.
- The CCL constructs are represented as a tree and the nodes can be modify in the user interface controls.

  The alert system is intended to be a multi-user software solution residing on a server machine.



When some change in the database occurs, new positions are added to the working memory and local changes are performed only for the affected items. The other items are not changed, and the inference is done very fast.

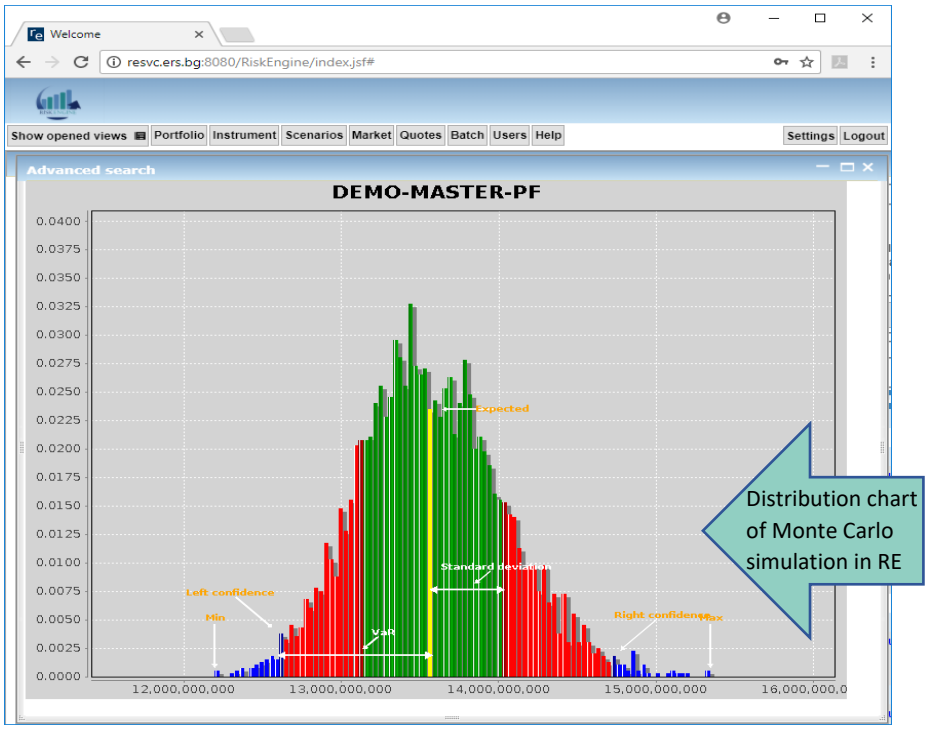
Monte Carlo Simulation Module in Risk Engine

Monte Carlo simulations are used to model the probability of different outcomes in a process that cannot be easily predicted due to the intervention of random variables. It is a technique used for understanding the impact of risk and uncertainty in prediction and forecasting models.

In Risk Engine, Monte Carlo simulation can successfully be applied to market, credit and spread VaR calculations in various modules. The VaR results are good for non-linear financial instruments, such as options, long-term cash flow assets and pay offs of structured products, as they retain the non-linear nature of assets.

Risk Engine uses structured Monte Carlo simulation for the calculation of parametric VaR/CoVaR, as well as for historical simulations. This sort of simulation produces future prices and VaR distributions of single financial positions or portfolios by applying numerical calculation procedures on a large set of probable scenarios, that are derived from historical series of market variables.

The implemented methodology improves the standard Monte Carlo approach by correcting the standard deviation and the form of the normal distribution through a common post-processing. This affects the calculation results in terms of accuracy and stability, if the simulation is repeated.



High-speed portfolio load:
For a portfolio load of **5.000 positions**, Risk Engine needs **~ 19 sec** (19223 ms).

High-speed calculation:
For a calculation of **5.000 VaR/CoVar positions and expected shortfall**, Risk Engine needs **~ 10.5 min** (645280 ms).

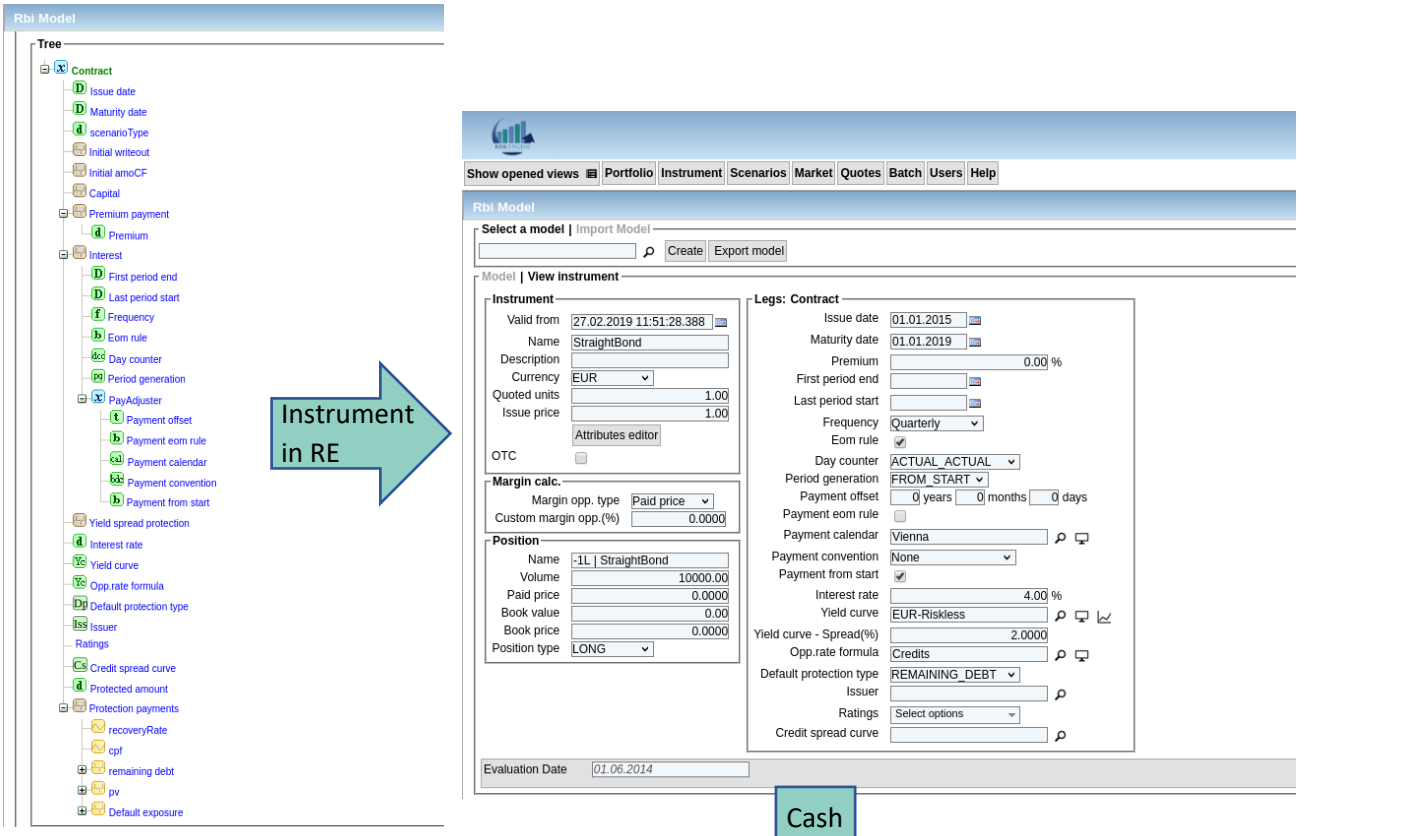
Instrument Types:	Number of Positions:	Percentage:
Fund	1045	20.88%
Cash Account	1705	34.07%
Premium Currency Investment	55	1.10%
RBI	880	17.58%
Money Market - Bullet Fix	110	2.20%
FX Outright	55	1.10%
Share	275	5.49%
Greece Government Bond GGB 2	55	1.10%
Total:	**5005**	

VaR Type:	Calculation Duration:
FX_VAR	~ 1.5 min. (85944 ms)
MC_VAR	~ 2 min. (111337 ms)
SPREAD_VAR	~ 1.5 min. (91550 ms)
SHARE_VAR	~ 1.5 min. (97323 ms)
RATE_VAR	~ 2 min. (116762 ms)
INTEREST_RATE_VAR	~ 2 min. (105271 ms)
Total:	**~ 10 min**

Rule-Based Instrument (RBI) Module in Risk Engine

The Rule-Based Instrument (RBI) enables the definition of a new complex instrument, based on a system of specific rules/formulas and grammar. The module then evaluates the output of such instruments at certain points in the future, called Price Sensitive Points (PSPs). The RBI model has three basic features:

- A tree of formulas, called 'tree model', that can be manipulated through control boxes *tree*, *node properties* and *new node*. By selecting a node in the tree, its properties – *name*, *formula* etc. – can be modified and new sub-nodes can be added to the currently selected node. The following types of nodes are supported:
  - *Constant* – a simple node used for values, allowing the user to manually fill in values for each PSP
  - *Formula* – can contain a formula (rule) referring to a set of nodes, that calculates its value on each PSP. The formula consists of function calls, arithmetic operators and references to other nodes in the tree
  - *Property* – this node type is used to define different non-stochastic features of the RBI, such as constants of *double* or *date type*, *day count conventions*, *financial calendars, etc*. Properties can, via their name, refer to rules of other nodes
  - *Cashflow* - similar to *formula* but can generate cashflows
- An attached structured market simulating the market environment. Used only for simulation purposes.
- A time plan of PSPs. A PSP designates a date on which something significant is going to happen, e.g. coupon payment, amortization payment, debt reduction, option right, etc.



A tree model in Risk Engine

Cashflow | Time Plan | Formula tree

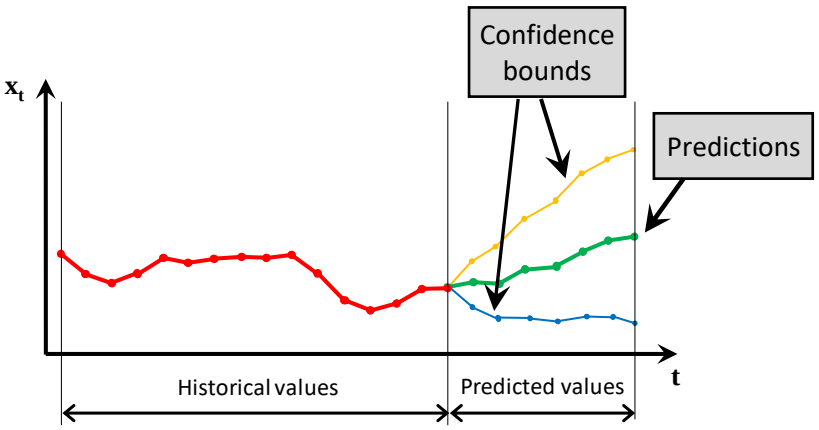
Contract

source.name	type	source.currency	period.start	period.end	fixingDate	paymentD...	yearFraction	discountFactor	value	presentValue
Contract	Fixed interest	EUR	01.01.2015	01.04.2015		01.01.2015	0.5863	0.986284	98.63	97.28
Contract	Fixed interest	EUR	01.04.2015	01.07.2015		01.04.2015	0.8329	0.977004	99.73	97.43
Contract	Fixed interest	EUR	01.07.2015	01.10.2015		01.07.2015	1.0822	0.966379	100.82	97.43
Contract	Fixed interest	EUR	01.10.2015	01.01.2016		01.10.2015	1.3342	0.964163	100.82	97.21
Contract	Fixed interest	EUR	01.01.2016	01.04.2016		01.01.2016	1.5863	0.961953	99.45	95.67
Contract	Fixed interest	EUR	01.04.2016	01.07.2016		01.04.2016	1.8349	0.959749	99.45	95.45
Contract	Fixed interest	EUR	01.07.2016	01.10.2016		01.07.2016	2.0836	0.956261	100.55	96.15
Contract	Fixed interest	EUR	01.10.2016	01.01.2017		01.10.2016	2.3349	0.950224	100.55	95.54
Contract	Fixed interest	EUR	01.01.2017	01.04.2017		01.01.2017	2.5863	0.944225	98.63	93.13
Contract	Fixed interest	EUR	01.04.2017	01.07.2017		01.04.2017	2.8329	0.938264	99.73	93.57
Contract	Fixed interest	EUR	01.07.2017	01.10.2017		01.07.2017	3.0822	0.931867	100.82	93.95
Contract	Fixed interest	EUR	01.10.2017	01.01.2018		01.10.2017	3.3342	0.924572	100.82	93.22
Contract	Fixed interest	EUR	01.01.2018	01.04.2018		01.01.2018	3.5863	0.917334	98.63	90.48
Contract	Fixed interest	EUR	01.04.2018	01.07.2018		01.04.2018	3.8329	0.910153	99.73	90.77
Contract	Fixed interest	EUR	01.07.2018	01.10.2018		01.07.2018	4.0822	0.902389	100.82	90.98
Contract	Fixed interest	EUR	01.10.2018	01.01.2019		01.10.2018	4.3342	0.893426	100.82	90.08
Contract	Pay off	EUR				01.01.2019	4.5863	0.884551	0.00	0.00
Contract	Amortization	EUR				01.01.2019	4.5863	0.884551	10,000.00	8,845.51

Module for Prediction of Financial Indicators in Risk Engine

Risk Engine performs univariate predictions on financial indicators, such as commodities, shares, market prices, etc.

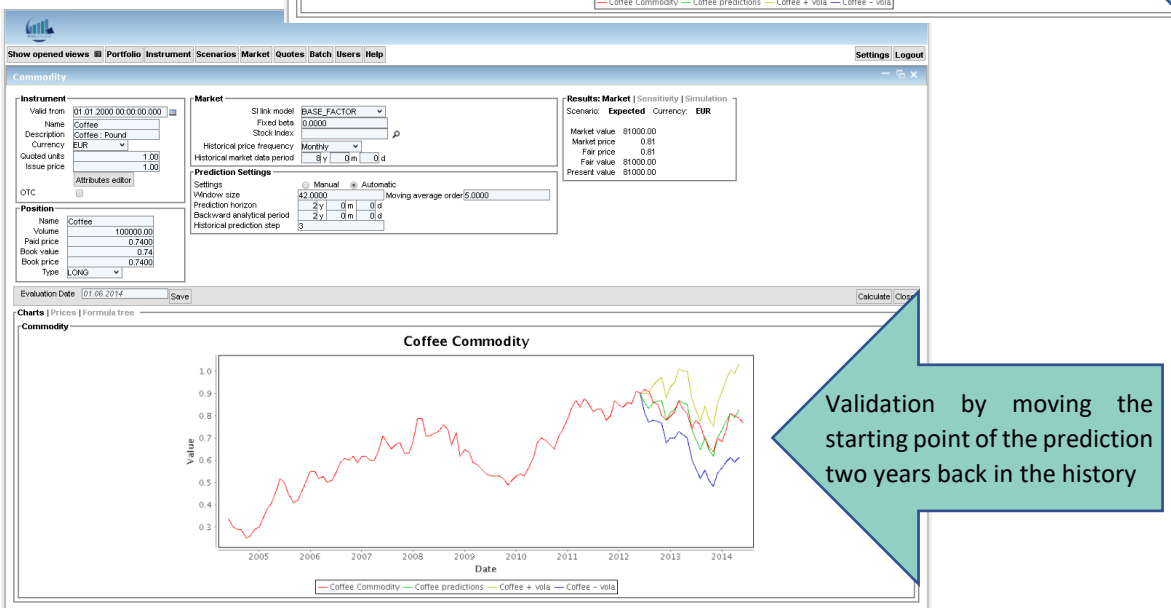
- Financial indicators are interpreted as discrete time series, representing sequences of observations that are expressed in the form of real numbers, ordered in time.
- These sequences of observations can be dependent, which allows their prediction.
- The accuracy of prediction depends on the nature of the time series, i.e. number of historical values, average value and variance, presence of additive and multiplicative trend and seasonality, outliers and missing values, quality of the series, etc. Risk Engine provides the possibility of filling missing values, using techniques such as Brownian Bridge.



The prediction of time series in Risk Engine is performed using a mathematical model and is executed in two main phases:

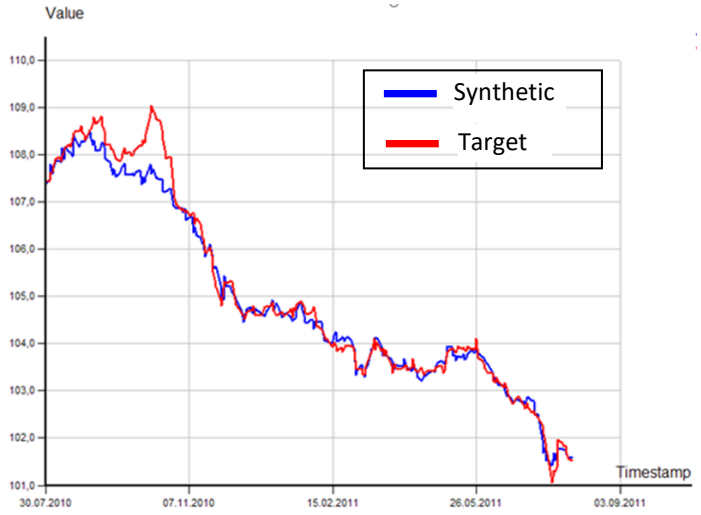
1. Model building, using available historical values, and
2. Prediction using the built model for future forecasts.

Prediction in Risk Engine:
coffee commodity prices for a two-year future time horizon, applying a model that is built by using historical data from the past eight years.



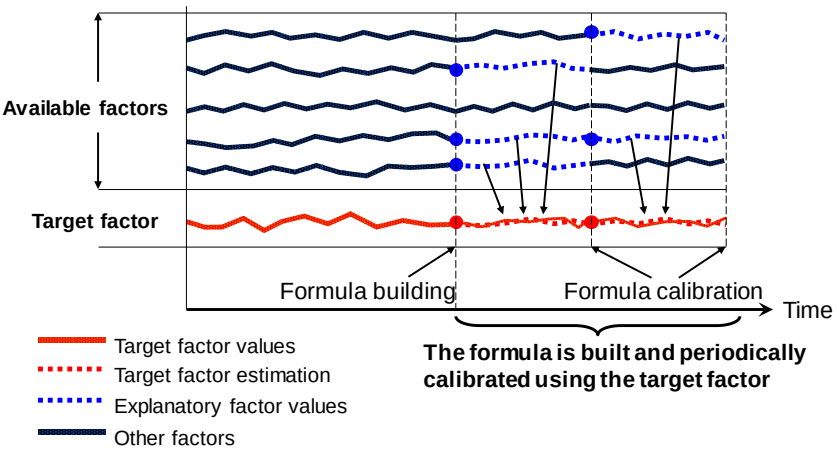
Multi-Factor Instrument (MFI) Module in Risk Engine

The Multi-Factor Instrument (MFI) allows the modelling of target instruments (funds, complex certificates, hybrid instruments and CPPIs) that have no pricing approach by using market factors with a known pricing approach (indices, spread curves or spread indexes, interest rates, inter banking rates, foreign exchange rates, prices, etc.) which are called 'explanatory factors'. The goal is to create a polynomial-based pricing expression that, as best as possible, reproduces the original price series of the target instrument via the explanatory series.

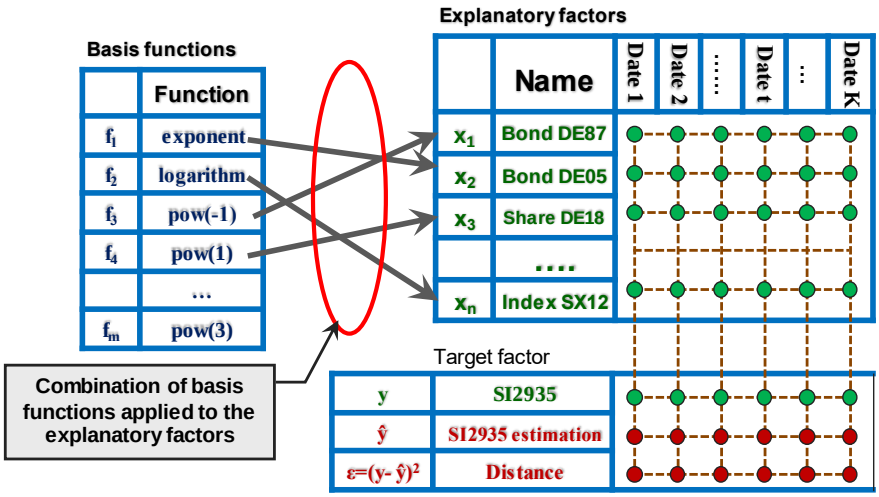


- The polynomial formula consists of regression coefficients and basic functions (sine, cosine, power, square root, etc.).
- When applied to historical values, the formula generates synthetic series that most fit the target instrument series.
- The created formula is based on historical data.
- Optionally, a decay factor can be used, increasing the significance of actual price values at the current date.

- The most appropriate explanatory factors for modelling are selected via automatic suggestion and/or are manually chosen.
- After the expression estimation step, the pricing expression can be used in the near future as a pricing model for the target instrument, enabling pricing, Value at Risk, volatility estimation and price projection.



The formula is built by selected explanatory factors and is periodically calibrated to produce best possible price estimations of market prices. This is achieved either by using the same explanatory factors or through new factors.



The modelling can be performed via:

- Absolute values – the expression calculates MFI prices from prices of selected factors.
- Relative/return values – the expression calculates the MFI return from returns of selected factors. The MFI price is then calculated from MFI spot price and MFI return.

$$\hat{y} = \beta_1 f_3(x_1) + \beta_2 f_1(x_2) + \ldots + \beta_n f_2(x_n) + \beta_{n+1} + \varepsilon$$

y – Target instrument price

$x_1, x_2, \ldots, x_n$ – Market factor price

$\beta_1, \beta_2, \ldots, \beta_n, \beta_{n+1}$ – Regression coefficients

$f_1, f_2, \ldots, f_m$ – Basis functions

ε – Error