Energy Management System

With ABT Optimization Engine

Technical Architecture

1.0 ABT optimization solution - Introduction:

This document describes the general architecture for an ABT (Availability Based Tariff) optimization solution to be deployed for a hydropower generation company. Though this document is aimed at a hydropower utility, apart from the inflow prediction engine, the architecture in its entirety is applicable to a generation utility handling other energy sources (even multiple energy sources).

The tariff structure for power generation utilities has undergone major revision under the ABT regime. The new tariff structure has been introduced to promote grid discipline by all players (generators and consumers) as well as to make the power generation domain more viable for private sector participation. As a result, the operation philosophy employed by power generation utilities also has undergone change under the ABT. The proposed solution aims to help the end-user (as a large power generation utility) to manage their resources in the most optimal and economic fashion under the new regime.

A component-based architecture has been proposed for the solution architecture. Besides the time-tested benefits of scalability and ease of maintenance, this framework offers a crucial benefit from the ABT point of view. As per CERC (Central Electricity Regulatory Commission) the ultimate objective of ABT is to migrate towards a self-regulating power market regime in a step-by-step fashion. Keeping this objective in view, as and when the power sector in India matures under a new tariff regime, further changes are to be introduced. These changes shall progressively move towards the self-regulating power market. A component-based framework will allow for easy adaptability of the solution under these successive changes, rather than rebuilding the solution framework each time a revision is announced.

Given below is the list of the major components proposed as part of the solution. A general architecture diagram of the solution is also provided in the following page. This diagram aims to depict how the different components are related to each other. The rest of the document comprises a brief description of the functionality of each of the modules.

1. Tariff modeling module
2. Tariff calculation module
3. Energy scheduling module (Generation schedule optimization)
4. Schedule exchange/communication module
5. Common (user) interface module
6. Data engine (incorporating search functionality and data export)
7. Reports module
8. Inflow prediction calculation engine
9. GTA (Generation Target Achievement) module
10. SCADA
11. Communication bus (for data exchange)

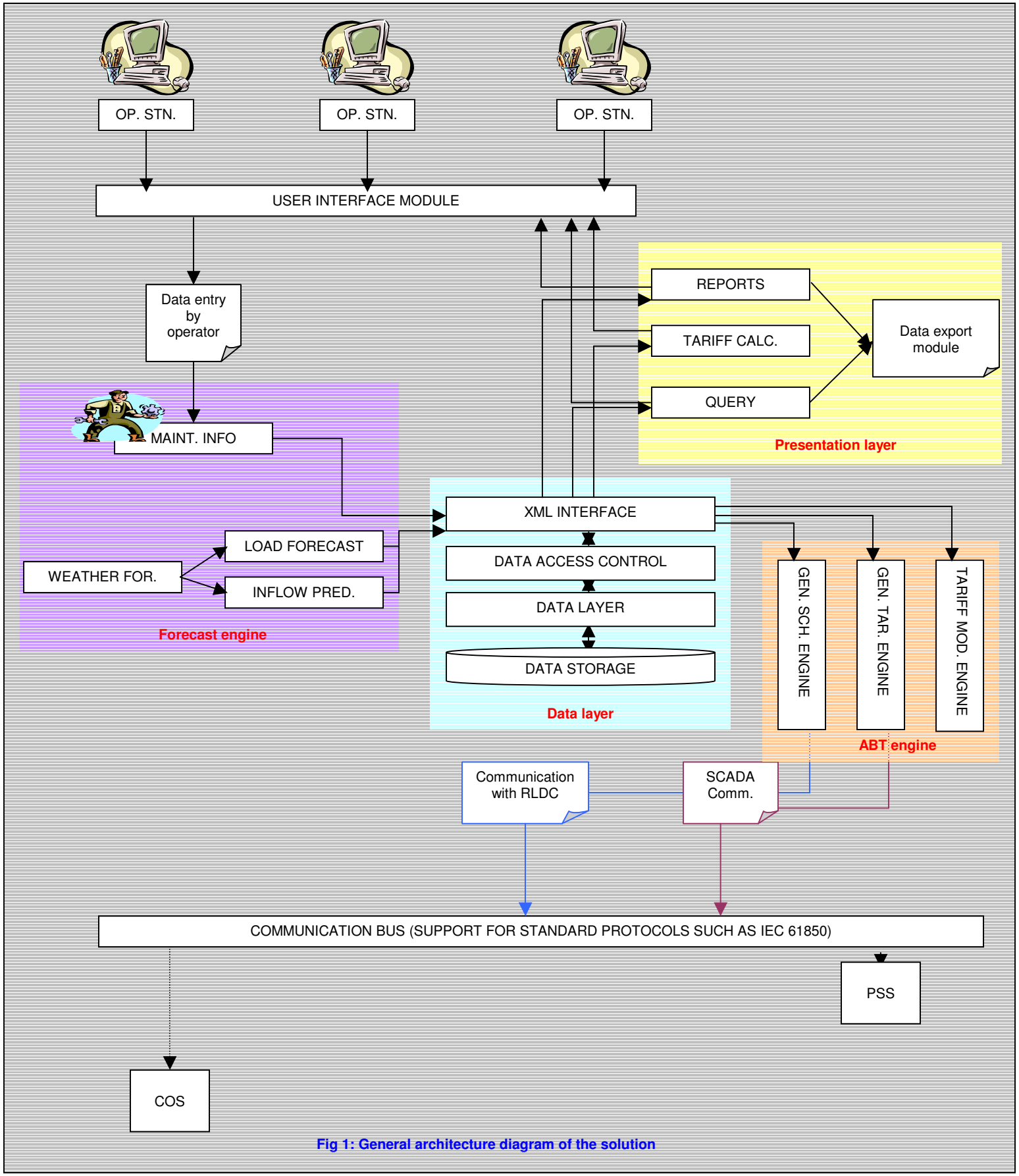

Fig 1: General architecture diagram of the solution

2.0 Architecture description

2.1 Data layer

Data layer acts as a single unit that deals with all data manipulation operations for the solution. To all external modules the data layer acts as a single unit that provides an XML interface to access, manipulate and modify data. Internally the data layer consists of the following sub-modules:

2.1.1 Data storage

Data storage shall consist of a robust and scalable RDBMS like Oracle or MS SQL Server. The RDBMS shall be responsible for data storage, back up and restore. Data archiving and restore utility as required by end-user shall be handled through the back-up/ restore mechanism provided with the database. Replication and networking mechanism provided by the RDBMS can also be used in case the data at one location needs to be reproduced at another.

2.1.2 Data layer

Data layer shall control all access to the data stored by the RDBMS. Data layer may be embedded within RDBMS or can be a separate module outside it. Data layer shall be responsible for handling all the meta-data related to the data storage. This shall include audit trails for data modifications, version management for data, timestamps for storage and modification, life span management of data and generation of data logs. All requirements of end-user related to data management shall be handled in this layer.

2.1.3 Access control

Access control layer shall be the security mechanism for the solution. This layer will control access to the data based on access control levels and other security constraints that are implemented in the system. Similar to data layer, access control may also be a part of the RDBMS or external to it.

2.1.4 XML layer

Irrespective of the RDBMS used, all external modules will be provided an XML interface for accessing and manipulating data. To the greatest extend possible the XML interface will conform to available international standards relevant to the particular domain. All mechanisms provided for querying and manipulating data through XML will use standard packages available. Though the XML interface may slightly compromise the performance compared to directly accessing the data in the RDBMS, this will be more than offset by the benefits of portability, scalability and ease of migration, upgradation and maintenance offered by an XML interface. Besides the XML interface can ensure that the system can interface with any number of external modules in the future without any rework.

2.2 Forecast engine

The forecast engine shall act as the ‘look-ahead’ mechanism for the whole solution. The purpose of this engine is to provide a best possible forecast of the demand and generation capacity of the system. This forecast will then enable the operator to plan the optimal course of operation that will maximize revenue within the framework of generation targets and ABT regime. The forecast engine consists of the following modules:

2.2.1 Maintenance and outage info. Module

This module will allow user to enter all available information that can affect the operation of the plant. Such information include planned maintenance schedules, forced outages planned, plant

data models, equipment physical and operational characteristics, hydro generation efficiency and degradation curves. While some part of this data may remain more or less static in the system, others will need update on regular intervals. The data provided through this module will be used in determining the short term and long term availability of the system.

2.2.2 Weather forecast

Weather forecast is external to the whole solution. The purpose of the weather forecast module provided with the solution is to collect forecast data from one or more external sources as required and make the same available in the data layer in appropriate format so that other forecast modules can male use of the weather data.

2.2.3 Load forecast

Load forecast module shall help in predicting the load for the subscriber area for a plant. Neural network models, similar day forecast models etc. could be used in forecasting the load. While the actual load on the system is determined by the schedule obtained from RLDC, having a reliable load forecasting solution at the plant level or corporate level is important for end-user as a utility company since this will greatly aid in the operation planning process.

2.2.4 Inflow forecast

An inflow forecast engine will be provided as part of the solution that will enable in predicting the short term and long-term water heads that will be available to the utility. The inflow forecast module will be based on a multi-input neural network algorithm. Inputs considered shall include parameters such as temperature, precipitation, evaporation, pond level, daily discharge data etc. Once the inflow prediction engine generates a model it will also allow for adjustments to the model so as to fine-tune the predicted results.

2.3 ABT engine

ABT engine is the most crucial part of the whole solution. All aspects of the solution that relates to the provision of the ABT are to be handled here. Considering the subsequent revisions anticipated for ABT, this component needs to be the most dynamic and scalable part of the whole solution. While other aspects of the system such as the forecast engine may remain more or less stable, the ABT engine (and perhaps the XML interface) may need to undergo multiple revisions during the lifetime of the solution. The ABT engine consists of three crucial sub-modules:

2.3.1 Tariff modeling engine

This component shall be responsible for modeling of all applicable tariffs under the ABT regime. The module will have four parts: first one will deal with capacity charges, second one with energy charges, third with UI (unscheduled interchange) charges and fourth for integrating other miscellaneous charges. While the fourth one may not be really required, it will be a customizable component that can be used to manage minor tariff structure revisions under ABT. The tariff calculation module will be a simple numerical calculation engine that computes tariff based on the model provided by the modeling engine. The tariff modeling engine, tariff calculation engine and invoice generation module under reports will act inline. The modeling engine will allow an authorized user to define and manipulate models using different entities that are relevant to tariff calculation such as availability, grid frequency, energy consumed etc. User can model different tariff equations using these standard (as well as user-defined) parameters and standard math functions.

2.3.2 Generation scheduling engine

The generation scheduling engine is responsible for enabling the operator to plan the optimal course of operation for the plant in the short and long term within the frameworks dictated by ABT

and generation targets. The generation scheduling engine (GSE) operates in multiple stages. In the first stage the GSE uses maintenance, outage and forecast data from the forecast engine to create a generation schedule that shall maximize revenues for the plant under the ABT regime. This generation schedule shall take into account the declared availability of the plant, operation reserves, inputs from the CMS (equipment condition monitoring system) etc. This generation schedule shall then be vetted by the operator and forwarded to the RLDC through the communication module. Once the schedule undergoes the due revision process and RLDC, the final 15-minute interval generation schedule expected of the utility is send back from the RLDC. In the second stage, the GSE prepares a new generation schedule that conforms to the schedule provided by the RLDC and maximizes revenues within that framework. It is this second stage schedule that shall act as the basis for daily operation of the plant. In the third stage the GSE acts as a contingency rescheduling engine to maximize UI charges or minimize UI losses. This third stage kicks into action when there is an unforeseen operating scenario either in the form of an unforeseen outage in the plant or in the form of considerable grid instability. In the former case, the objective of the GSE shall be to minimize UI losses while in the latter case the objective shall be to maximize UI revenues.

2.3.3 Generation target achievement engine

The generation target achievement engine (GTA) shall assist the user in the real time operation of the plant. The GTA shall act inline with the SCADA/DAS in the plant, the generation scheduling engine and the equipment condition monitoring system. The GTA shall enable the user to determine the optimal operation course within the frameworks of generation schedule, operation philosophy (such as avoiding unnecessary control operations) as well as alarms and warnings from the field generated through the SCADA. Architecture-wise, it may be optimal for the GTA to be embedded within the SCADA solution or working in a tightly integrated fashion with the SCADA since most GTA itself concerns mostly with real time decisions and operation akin to SCADA.

2.4 Data presentation layer

The data presentation layer shall perform the function of translating data from the data layer to a form suitable for display to the user. The data presentation layer works inline with the user interface layer. It is the user interface layer that provides data to the user through a browser and the “look and feel” of the interface is also decided at the user interface layer. The data presentation layer is responsible for deciding what data the user requires and how the data shall be formatted before presentation to the user. The presentation layer consists of the following modules:

2.4.1 Report engine

The report engine shall allow the user to select from a wide array of reports. For each selected report user can specify filter options such as date range, data range (above or below a certain value) etc. User can also specify whether the data needs to be presented in a tabular form or other graphical forms. Once the report is generated, user can decide to save, print, e-mail or export the report to other formats.

2.4.2 Tariff calculation engine

Tariff calculation engine will use the tariff model provided by the modeling engine and compute the applicable tariff for a specified duration. The tariff calculation engine shall keep track of different tariff models as and when they are modified. This will enable the engine to use the relevant model for each different period, For example, while calculating the tariff for the first quarter for the last year the engine will use the tariff model applicable at that time which may differ from the tariff model applicable for the first quarter of this year. The tariff calculation engine shall allow for generation, saving and printing of invoices in the format prescribed by end-user.

2.4.3 Query engine

Query engine will allow a trained user to define and execute queries against the data layer. The solution shall allow for a simple query language to be defined based on the requirement of end user. This may be based on such existing standard as XQL (XML query language) or ANSI SQL (Structured Query Language). Or a simple query interface that conforms more to plain English can be developed (somewhat along the lines of English query interface provided with MS SQL Server 2000).

2.5 Data export module

Data export module is an add-on feature that shall enable the user to export data generated in the presentation layer to be exported to other formats such as MS Excel or Acrobat PDF.

In addition to the above modules, the solution shall contain a user interface module and a communication module:

2.6 User interface module

The user interface module shall be responsible for making all the data available to users through a browser interface (such as Internet Explorer or Netscape Navigator). The module will ensure that all interfaces conform to end-user corporate standards in terms of 'look and feel'. Given that data from data layer is being made available as XML, standard presentation technologies such as XSL or CSS can be used define the user interface layer.

2.7 Communication module

Communication module shall handle data exchange from the solution to all external modules such as PSS, COS etc. Standard communication protocols applicable to the domain available from international bodies such as IEC, IEEE shall be used in the communication module. The actual protocol(s) to be employed shall be finalized taking into account the communication requirements, communication infrastructure available (Ethernet, modem, dial-up etc.) and the SCADA or other solution being used.