MOSFET technology and offer an improved trip-time performance.

A software logic enables the input and output channels to be assigned to the various functions. A time stamp is attached to all the data such as currents, voltages, binary inputs, events and diagnostic information acquired by a bay unit.

Where more analog and binary inputs are needed, several bay units can be combined to form a feeder/bus coupler bay (e.g. a bus coupler bay with CTs on both sides of the bus-tie breaker requires two bay units).

The bay unit is provided with local intelligence and performs local protection (e.g. breaker failure, end fault, breaker pole discrepancy) as well as the event and disturbance recording.

In the event that the central unit is out of operation or the optical fiber communication is disrupted an alarm is generated. The bay unit will continue to operate and all local protection as well as the recorders (event and disturbance) will remain fully functional (stand-alone operation).

The hardware structure is based on a closed, monolithic casing and presented in two mounting solutions:

- Without LHMI: ideal solution if convenient access to all information via the central unit or by an existing substation automation system is sufficient.
- With LHMI and 15 programmable LEDs (Figure 7): ideal solution for distributed and kiosk mounting (AIS), since all information is available in the bay.
  For this option it is possible to have the LHMI either built in or connected via a flexible cable to a fixed mounting position.

Additional plug-and-play functionality

Bay units can be added to an existing REB500 system in a simple way. Due to the modular and flexible architecture of the software, integration of new units is easily achieved.

In the event of a failure, a bay unit can be easily replaced. During system startup the new bay unit requests its address, this can be entered directly via its LHMI. The necessary setting values and configuration data are then downloaded automatically.

Figure 7. Bay Unit

Central unit (500CU04)

The hardware structure is based on a closed, monolithic casing.

The central unit is the system manager, i.e. it configures the system, contains the busbar replica, assigns bays within the system, manages the sets of operating parameters, acts as REB500 process bus controller, assures synchronization of the system and communicates with the station control and monitoring system.

The variables for the busbar protection function are derived dynamically from the process data provided by the bay units.

The process data is transferred to the central processor via the REB500 process bus interface. The central unit is able to handle data from up to 60 bay units and evaluate up to 32 bus zones.
In addition to processing the protection zone data, the central unit provides a disturbance recorder for all 32 bus zones, recording the main data of the busbar protection to facilitate quick fault analysis.

The central unit offers 9 binary inputs and 19 binary outputs for central commands and signals (e.g. external bus zone trip, trip-reset etc.). Additional 9 binary inputs and 9 binary outputs are optional available.

The central unit comprises a local HMI with 15 programmable LEDs (Figure 8) including a front Ethernet port for HMI connection within the local area network.

Figure 8. Central Unit

5. Functionality

Busbar protection

The protection algorithms are based on two well-proven measuring principles which have been applied successfully in earlier ABB low-impedance busbar protection systems:

a) Stabilized differential current measurement principle
b) Phase comparison measurement principle

The algorithms process complex current vectors which are obtained by Fourier analysis and only contain the fundamental frequency component. Any DC component and harmonics are suppressed.

Stabilized differential current measurement

The first measuring principle uses a stabilized differential current algorithm. The currents are evaluated individually for each of the phases and each section of a busbar (protection zone).

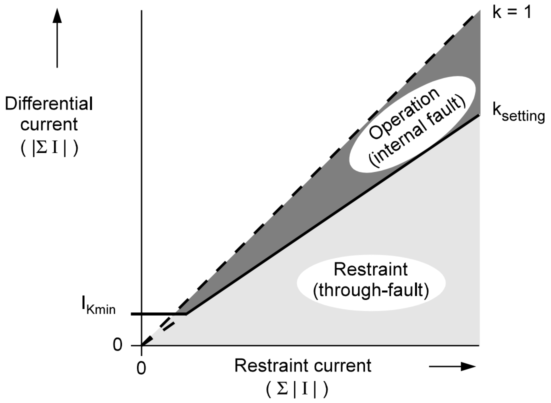

Figure 9. Tripping characteristic of the stabilized differential current algorithm

In Figure 9, the differential current is

$$I_{Diff} = \left|\sum_{n=1}^{N} \underline{I}_{L_n}\right|$$

and the restraint current is

$$I_{Rest} = \sum_{n=1}^{N} \left|\underline{I}_{L_n}\right|$$

where N is the number of feeders.

The following two conditions have to be accomplished for the detection of an internal fault:

$$k_{st} = \frac{I_{Diff}}{I_{Rest}} > k_{st\,max} \quad \text{AND} \quad I_{Diff} > I_{K\,min}$$

where

k_{st}	stabilizing factor
$k_{st\,max}$	stabilization factor limit (typically 0.80)
$I_{K\,min}$	differential current pick-up value

The above calculations and evaluations are performed by the central unit.

Phase comparison

The second measuring principle determines the direction of energy flow and involves comparing the phases of the currents of all the feeders connected to a busbar section.

The fundamental frequency current phasors $\varphi_1, \ldots, \varphi_n$ are compared. In the case of an internal fault, all of the feeder currents have almost the same phase angle, while in normal operation or during an external fault at least one current is approximately 180° out of phase with the others.

$$\varphi_n = \text{arctan}\left[\frac{\text{Im}(\underline{I}_{L_n})}{\text{Re}(\underline{I}_{L_n})}\right]$$

The algorithm detects an internal fault when the difference between the phase angles of all the feeder currents lies within the tripping angle of the phase comparator (see Figure 10).

Processing

The task of processing the algorithms is shared between the bay units and the central processing unit. Each of the bay units continuously monitors the currents of its own feeder, preprocesses them accordingly and then filters the resulting data according to a Fourier function. The analog data filtered in this way is then transferred at regular intervals to the central processing unit running the busbar protection algorithms.

Depending on the phase-angle of the fault, the tripping time at $I_{Diff}/I_{k,min} \geq 5$ is typically 15 ms including the auxiliary tripping relay.

Optionally, the tripping signal can be interlocked by a current or voltage release criterion in the bay unit that enables tripping only when a current above a certain minimum is flowing, or the voltage is below a certain value, respectively.