Advant® OCS

ABB Advant Energy Management Systems

Type Circuits & Functions

3BSE001264/A

3BNL ITC 001 RB10

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1 Introduction

1.1 General

This document, "*ABB Advant Energy Management Systems Type Circuits & Functions*" for Master software, contains a brief description of all functions of the ABB Advant Energy Management Systems.

Advant EMS provides economical control and supervision of the power-generation and -supply in industrial plants. The main reason for considering the Advant EMS is very often the need for Load Shedding. This system drastically increases the overall plant safety by assuring electrical power and steam for critical loads and avoids blackouts. The costs, caused by production losses, of a complete blackout easily can go up to one million USD per blackout. With the provided tools it is possible to ensure safe operations with less personnel. Better, faster and more comprehensive information from the process is thus a necessity. For many (petro-)chemical, steel and cement industries the costs for energy form at least 30-50 % of the production costs. The Advant EMS increases the efficiency and the pay back time of the system is very short (<less than 2 years).

Advant EMS allows for more critical designs of the electrical equipment in a plant. The Advant EMS will re-arrange generation, importation and loading in such a way that the individual generators, reactors, transformers, and tie-lines are operated well within their specifications. The integration and serial communication with Motor Control Centres, Protection Units, Governor controllers, Variable Speed Drives and other subsystems give high savings in copper wiring and maintenance costs. The optical connections provide a rigid network that does not suffer from electromagnetic interference.

Since 1986 ABB Systemen BV in Rotterdam, the Netherlands has been actively working in the field of Industrial Electrical Energy Management Systems (Advant EMS). Realising projects all around the world, the power automation group has built up specific application know how regarding the control and monitoring of electricity networks for industrial process plants. The Advant EMS functionality has gained wide acceptance among its users.

Since January 1996 ABB Systemen BV is the product responsible unit (PRU) for the applications for this type of energy management systems within the business unit COG of ABB IAD.

A wide range of products is available to allow for a cost-efficient and reliable engineering of the EMS systems. The well tested and documented products (software type circuits and system software modules) guarantee a significantly decreased project execution time and (even more important) shorter commissioning periods.

In case, projects are run by the local ABB Automation companies or Regional Centres, ABB Automation Benelux can support these projects either by supporting man-hours or by providing tools like project quality control plans, frames for functional design specifications and pre-defined project time schedules. These tools help in order to achieve a smooth and optimised project execution.

For a more complete exposition of ABB Advant Energy Management Systems, please contact:

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1.2 Advant EMS type circuit concept

ABB Advant Energy **M**anagement **S**ystems control applications are configured in AMPL, a function-block language with graphic representation. The language is characterized by each function being seen as a building block with inputs and outputs. The function of such a block can be simple, such as a logic AND function, or complex, such as a complete adaptive PID regulator. A program written in AMPL is referred to as an AMPL program and the building blocks are called PC-elements. The range of ready-to-use PC-elements is wide and powerful.

Control loops can be combined with motor control, start-up, and shut-down sequences and fast interlocking logic, all in the same control program and using the same high-level function block oriented language, AMPL.

A controller can be configured in AMPL fully on-line, i.e. with the programs running and controlling the process. If required, a part of an AMPL program, a complete AMPL program or the whole controller can be blocked during configuration. It is also possible to develop programs off-line in an engineering station and load them into the controller at a later stage.

In addition to functional PC-elements, AMPL contains a number of structural elements for division of an AMPL program into suitable modules which can be managed and executed individually. The modules can be given different cycle-times and priorities so that both fast and slow control operations can be managed by the same AMPL program.

The inputs and outputs of an element are connected to the inputs and outputs of other elements or to process I/O points. Picking these elements and making these connections constitute the configuration work. The resulting AMPL program can then be documented graphically.

To boost productivity of building energy management applications even further, ABB Systemen in Rotterdam the Netherlands, has developed as PRU, ABB Advant EMS within the BU COG (chemical, oil and gas), type circuits. A type circuit is basically a black box containing all logic needed to realize a certain functionality. The type circuit has input- and output terminals which makes it possible to connect it to additional logic or signals.

When the type circuits are loaded into the engineering environment, Advant Engineering Station 100/500 Series, the engineer will use them as any other PC-element. A type circuit consists of symbol declarations, instructions creating or modifying data base elements and PC-elements. Type circuits can be instantiated several times in process controllers. By assigning different values to symbols at instantiation, the function of the type circuit instance can vary. The type circuits can only be seen in an off line mode. If the type circuits provided by the PRU ABB Advant EMS do not meet the requirements in a specific project, it is possible to make own type circuits. The original type circuits can then be used as a base for these modified versions.

All type circuits are prepared, validated and tested for the latest Function Chart Builder version and for the latest MasterPiece 200/1 or Advant Controller 400 series targets. The installation of AdvaBuild for Windows is described in the Advant Station 100 Series Engineering Station User's Guide.

1.3 Prerequisite

A prerequisite for the usage of ABB Advant EMS type circuits is:

- *MasterPiece 200/1 with XMP240/QMP240 SW or higher*
- *Advant Controller 400 Series 1.0 or higher*

1.4 Purpose of the manual

The purpose of this manual is to give information about the powerful library of the ABB Advant EMS type circuits and functions.

1.5 Related documents

In order to provide all the information needed for the use of the different type circuits, please refer to the individual functional descriptions of each type circuit, which is available from the PRU ABB Advant EMS.

In addition to the unified documentation for the PRU ABB Advant EMS type circuits, there are other standard manuals which document individual types of program functions. Information in this manual is based on the following documents:

- *PC Elements Advant Controller 400 Series Reference Manual*
- *Data Base Elements Advant Controller 400 Series Reference Manual*
- *AdvaCommand Basic Functions User's Guide*
- *AdvaCommand User Interface Reference Manual*
- *Function Chart Builder User's Manual*
- *Advant Station 100 Series Engineering*
- *AMPL Application Building Reference Manual*

2 Network Configuration Determination

2.1 General

The *"Network Configuration Determination"* function analyses the electrical network configuration determined by the status of the tie-line breakers, buscouplers and generator breakers.

The results of this function are used by other functions, such as the later described functions auto sequencer, load shedding, reacceleration, active power control, reactive power control, transformer control and generator control.

2.2 Network determination

The electrical network has a number of breakers of which the status determine the actual network configuration(s). These breakers are applied for the following intrinsic functions, and are used in the programs for network determination:

- *connect/disconnect busbars*

  the status of these breakers are used to determine the configuration of busbars
- *connect/disconnect generating capacity or imported power to/from a bus*

  the status of these breakers are used to calculate the available power on a bus
- *connect/disconnect loads to/from a bus*

  the status of these breakers are used to calculate the actual load on a bus

When the status of the breakers (connect/disconnect busbars) are read, the function generates the actual network configuration. The results are written in a register. The outputs of the register are used by the other functions.

In the electrical network, many possible network configurations can be determined. A network configuration is defined by the checked and approved, opened or closed position of the breakers involved. The status of these breakers are input for the network determination.

Each breaker can have two positions, either opened or closed. If one of these breakers has an intermediate position, then this is a non-existing configuration and an audible alarm is created. It is assumed that the network configuration change is not succeeded. An electrical island is only of interest if it consists of at least one machine. If, for example, a maximum of 6 machines are in operation, no more than 6 islands can be formed simultaneously.

3 Load shedding

3.1 General

The load shedding system has to ensure the availability of electrical power to all essential and most critical loads in the plant. This is achieved by switching off non essential loads in case of a lack of power in the plant electrical network, or parts of the plant electrical network. A lack of electrical power can be caused by loss of generation capacity or disconnection from the public power company supply. The load shedding system for a substation in a substation node is realized with:

- *one type circuit for each substation*
- *one type circuit for each panelhalf in the substation*
- *one type circuit for each sheddable load*

The load shedding system can be implemented by one or more of the following functions:

- *primary load shedding*
- *frequency load shedding*
- *manual load shedding*
- *maximum peak power demand shedding*

Main input to the load shedding system is the register received from another function of the ABB Advant EMS function called *"Network Configuration Determination"*, which determines the configuration of the electrical network. The configuration is determined from the checked breaker positions.

Secondly, load shedding needs data from the loadflow in the network. Data regarding the loads on the busses and the power generated by each generator is sent to the central load shedding function by analogue inputs and software has already checked the validity of the data. Where available, the measured power of each load is used. This data can be received from the analogue inputs in the process controllers or via serial links to the MCC's. When there is no power measurement available for a particular load, the belonging position of the breaker is used together with the nominal power value. Load shedding uses data representing the loadflow in the network, which is at least 2 seconds old, to prevent load shedding from using data which was obtained while the network was already in a faulty and thus unstable condition.

The third group of data needed by load shedding is the operator input. For the load shedding functionality maximum 20 priorities are used. For each load all priorities can be defined by the operator. Priority 20 is reserved for all non-sheddable loads or loads which are disabled for load shedding. Within each priority also 10 groups can be assigned. A group is the smallest sheddable unit. For each load with the load shedding option, the operator from central point of control is able to change the priority and enable/disable the load shedding function.

The operating time from opening a circuit and read in by a digital input in any of the Advant Controllers to giving the load shed command, at a particular output in any of the Advant Controllers, is maximum 150 milliseconds. For the crisis signals, the transducer reading is not used when determining whether a breaker is open. This is because of the fact the transducer takes approximately 300 milliseconds to settle, this time would make the load shedding action too slow. Preferred, if possible, a 2 out of 3 reading is to be used for the circuit breaker positions, which are used as crisis signals.

3.2 Primary load shedding

The following main functions are included in the primary load shedding system:

- *continuously checking changes into the total electrical network configuration*
- *continuously checking the energy balance in every electrical island configuration*
- *calculation of the dynamic priority load tables*
- *generation of the load shed command when needed*
- *supervision of the total ABB Advant EMS computer system*
- *generation of reports after load shedding*
- *informing and guiding of the operators*

The load shedding system continuously checks whether changes in the island configuration have occurred. As soon as a change occurs, for example tripping of a generator, the load shedding system starts checking all the individual island configurations. For every island configuration, the energy balance has to be calculated. If the load in this island configuration exceeds the available generated power, it is necessary to shed the surplus of loads.

For every island configuration, which is momentarily in a steady state condition, the load shedding system has to monitor continuously the power available from the generators in that particular island configuration, since losing a generator or losing part of the capacity of a generator might cause the need for load shedding.

As soon as load shedding is started due to a change in the electrical network configuration, not meaning that a real shed command is generated, the system starts calculating the dynamic priority load shed tables. Input for this calculation is the data in the island configuration and the priority load tables for the several busses. For every bus on which there are sheddable loads, such a priority load table is assembled.

The priority load table for every bus is assembled in order of priority. Calculation of the priority load table is done in the background. From this priority load table an accumulated priority load table per bus is obtained. As soon as load shedding is started, an accumulated priority load table for the whole island configuration is calculated. If the result of the energy balance calculation leads to the conclusion that load shedding is needed, the amount of power to be shed is also obtained from this energy balance calculation. This amount is now compared with the contents of the accumulated priority load table for the island configuration. The load shed command is generated and sent fast to the unit where the loads are actually connected.

The primary load shedding functionality is implemented into two parts:

- *central part*
- *substation part*

The central part of primary load shedding functionality is implemented in the central node. The substation part of primary load shedding functionality is implemented in the one or more substation nodes.

For small load shedding applications, the central- and the substation part of the primary load shedding can be implemented into central node.

3.2.1 Central part of primary load shedding

The central part of primary load shedding functionality is implemented in the central node where is determined:

- *the load shed priority*
- *the substation for fine tuning*
- *the load which should be shed by fine tuning*

Determination of the group to shed, so called *fine tuning*, is handled in the substation node. The next sub-chapters are describing most of the load shedding functions implemented in the central node, divided into slow and fast functions, in connection with the load shedding function in the substation.

3.2.1.1 Priority load tables

Per panelhalf an accumulated priority load table is calculated. An accumulated priority load table is a table where in each priority the load is the sum of loads of all preceding priorities, see also figure 3-1.

The table is based on the available power, not on the lack of power, and starts at priority 20 instead of priority 1. In this way it is not necessary to wait for a priority load table refresh from the substations.

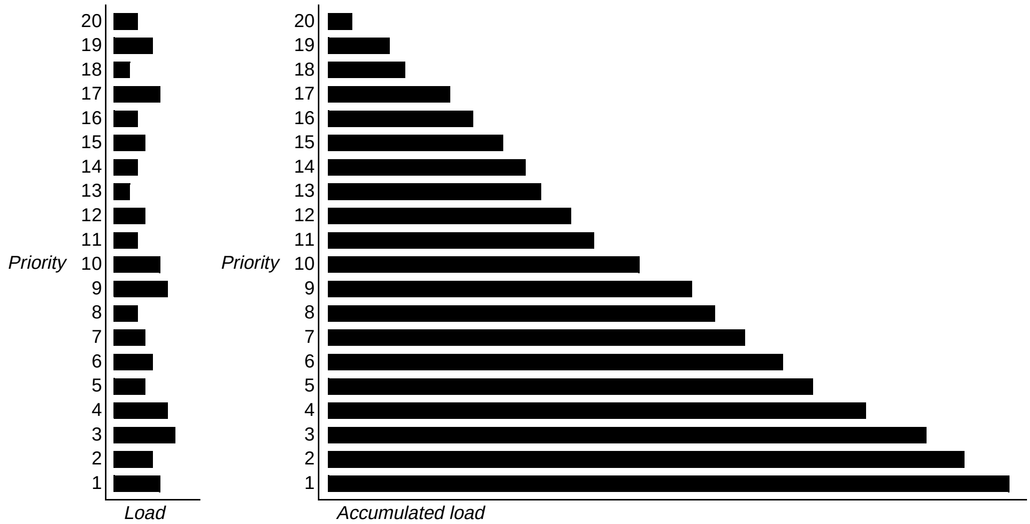

Figure 3-1. Accumulated priority load table

These accumulated priority load tables are compiled from substation priority load tables. These substation priority load tables do have a certain inaccuracy because:

- *the substation priority load tables are from 0.. 2 minutes old*
- *the substation priority load tables are made up of:*
  - *MW measurement, which causes no inaccuracy*
  - *MW value calculated by a current measurement and a fixed voltage value and a fixed power factor value, which causes an inaccuracy*
  - *MW value as a fixed nominal MW value with a possible correction, which causes a larger inaccuracy*
- *substation power calculation assume a fixed power factor for all motors*
- *the substation priority load tables do not include the non sheddable loads with no priority (next to not sheddable loads with priority* 20*, there are also not sheddable loads with no priority)*

During normal situations, per island, generated power and total load should be equal. To avoid instability when load shedding, the accumulated priority load tables per island should be adjusted. This is done by adding the difference between the priority load tables and the measured busbar load at the feeder breakers to priority 20.

If a communication error with the substation node is detected, all loads will be shifted to priority 20, and thus being not sheddable.

3.2.1.2 Upstream breakers

The fast part of the breaker control of the upstream breakers is integrated in the load shedding software, to be able to meet the time constraints of the load shed commands.

The load shedding is activated if a change in a object is detected or if the operator gives a command to reset load shedding, unless load shedding is blocked by the operator.

To identify which busbar is feeding which substation panelhalf, the upstream- and downstream breaker positions are used. This information is sent to each substation to be used by several type circuits.

3.2.1.3 Compensation of priority load tables

Normally, measured generator power and attached loads should be equal. There can be a value discrepancy between the priority load tables and the generated power which could erroneously shed loads. This discrepancy is caused by:

- *delay in measured generated power is 2 seconds, delay in priority load tables update can be up to 2 minutes*
- *loads in the priority load table are calculated from motor current and a fixed busbar voltage and a motor power factor value which is equal for all motors, taken care by the motor control type circuit*
- *not all plant loads are represented in the priority load tables*

To compensate for these errors, the difference between the sum of the feeder circuit breaker-loads and the priority load table is taken and added to priority 20. This is done per busbar, an other option is to do this per substation, in other words, not taking the feeder circuit breaker loads but the substation transformer load measurements to compensate.

3.2.1.4 Load shedding island

At this point the shed commands are determined, which have to be sent to the substation nodes. A shed command includes a priority, an ordernumber and a restload per busbar.

The power balance is calculated by comparing the available power with the accumulated priority load table of the bar. In case that the island includes more busbars, the corresponding accumulated priority load tables are summed.

First is checked until which priority all connected substations should shed loads this yields the priority. The load which is shed by doing this is subtracted from the available power, see also figure 3-2.

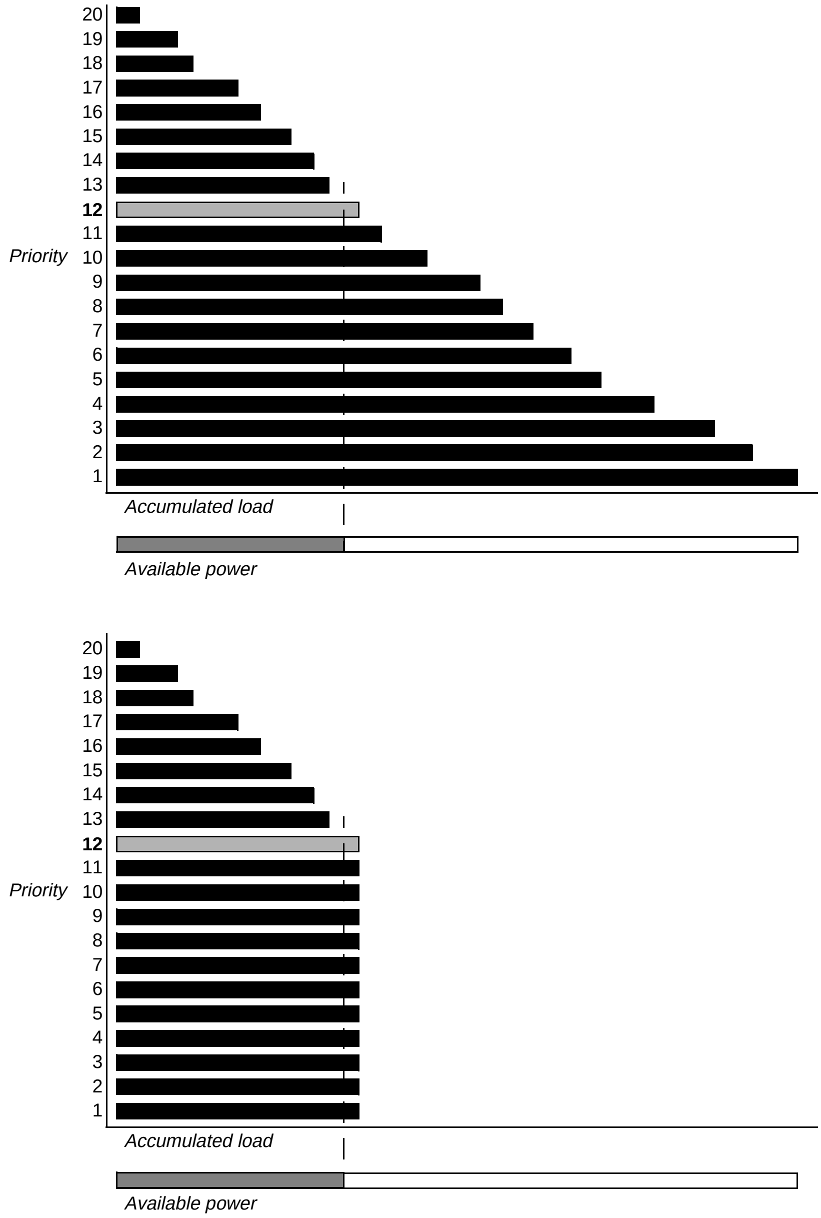

Figure 3-2. Determination load shed priority

After this is checked with the remaining load, which substations should shed a next higher priority. The *priority number* of the last substation where a next priority should be shed yields the *order number*.

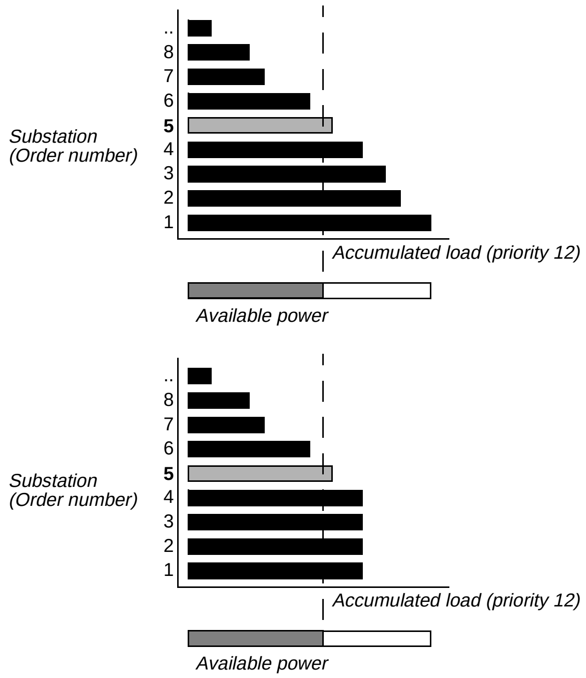

Figure 3-3. Determination order number

The sequence of this second shed action, which is executed in order of importance of substation, is defined by the order number. The highest order number is the most important substation.

The load which is shed by executing this last action, is subtracted from the available power. The remaining load is the restload. The substation with ordernumber equal to the order number found this way should use the restload to execute the fine tuning. Fine tuning sheds the groups in the substation until sufficient load is shed.

3.2.1.5 Shed commands to substations

The priority calculated by the primary load shedding is compared with the calculation of the thermal load shedding and manual load shedding. The commands which result in the shedding of the largest amount of load are passed to the substations. The shed commands are sent to the substation nodes, using a fast communication PC-element, to make sure that the time between detecting a circuit breaker position change in the central node and opening a substation motor breaker does not exceed the stability requirements.

3.2.1.6 Check update load tables

Substation priority load tables are cyclically updated by the central node, default every 2 minutes. If all priority load table data transfer “valid communication bits” for all substation are set valid, all tables are updated and the load shedding calculation in the fast part is started.

3.2.1.7 Power calculations

Power measurements from the generator circuit breakers, public power company in coming circuit breakers and the substation feeder circuit breakers are taken from the metering and monitoring function module and delayed for 2 seconds to assure stability when shedding. Nominal power is calculated by adding a fixed value or a percentage to the actual generator power to represent the generator ability in catching up when load is increased.

3.2.2 Substation part of primary load shedding

For load shedding purposes the handling of the following functionality is implemented in the substation nodes:

- *priority, group and inhibit and enable load shedding per load*
- *priority load tables*
- *shed commands from the central node*

The substation in the substation node receives the following shed commands from the central node:

- *network information*
- *priority*
- *order number*
- *rest load*

3.2.2.1 Network information

With the network information, information is given to each substation panel-half to which load busbar it is attached, e.g. left- or right side or both.

This information can be calculated by the substation itself, which requires the upstream circuit breaker position information from the central node. To keep the network information in the substation node consistent with the central node, the upstream breaker positions are sent simultaneously with the load shedding information.

3.2.2.2 Priority

All loads up to and including this priority are shed in the island. This priority is received from the central node. Depending on the network information, the loads up to and including this priority are shed.

3.2.2.3 Ordernumber

All substations with an ordernumber *smaller* than the ordernumbers received will shed an extra complete priority with the priorities, as described into chapter 3.2.2.2. These are the less important substations.

All substations with an ordernumber *larger* than the ordernumbers received, will shed only the priority as described into chapter 3.2.2.2. These are the more important substations.

The substation with an ordernumber *equal* to the ordernumbers received, will execute the fine tuning using the calculated restload.

3.2.2.4 Fine tuning

The restload is compared with the total load in group 0. If the rest load is larger than the load of group 0, group 0 will be shed. For the next iteration step the load of group 1 will be added to the load of group 0, this sum is compared with the restload. If the restload is still larger than the load of the next group (2) is added. This action is repeated until the sum is larger than the restload, if so, this and the preceding group will be shed.

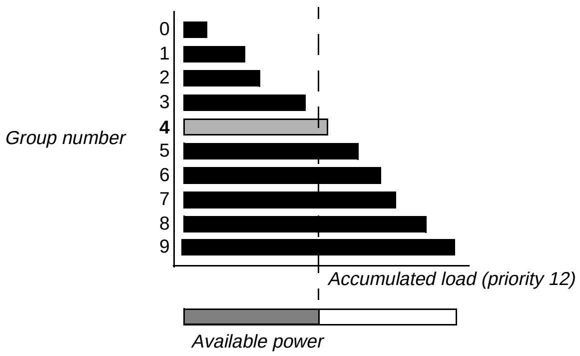

Figure 3-4. Fine Tuning

3.3 Frequency load shedding

This function is more or less the backup for the primary load shedding function, which is described into chapter 3.2. When the primary load shedding fails due to wrong inputs, this function will shed the loads. Frequency load shedding not only takes the absolute frequency limits into account, but also calculates the df/dt. This gives a more accurate load shedding. The frequency limits are read in from frequency relays by digital inputs in the Advant Controller.

3.4 Manual load shedding

The operator can issue a plant-wide shed priority up to 20. To assist the operator in assessing how much load will be shed if the operator issues a manual load shedding priority, in the main load shedding process display an accumulated priority load table for the total actual plant load per priority is presented.

3.5 Maximum peak power demand shedding

Some priorities are shed as soon as the power taken from the public grid is tending to supersede the maximum allowed amount when the in-house generation is maximised. This import maximum is based on periodically power demand. In this case, the operator can deactivate the mechanism, and also determine up and until which priorities may be shed automatically by this function. Certain priorities can be inhibit from maximum peak power shed. Before the shed command, an audible alarm is created. So an action can be taken, if there is time, to overcome the situation.

3.6 Operator interface

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Island_1 Accumulated Load Table

Priority	Acc. Load	S10B1 Acc. Load	S10B2 Acc. Load	S11B1 Acc. Load	S12C1 Acc. Load	S12C2 Acc. Load	S23B1 Acc. Load
1	2300	1100	0	0	1200	0	0
2	2976	1196	0	580	1200	0	0
3	3836	1196	0	580	2060	0	4204
4	5103	1196	0	580	3250	77	4950
5	5923	1196	0	580	4070	77	5607
6	6723	1196	0	580	4870	77	5607
7	9303	1196	0	3160	4870	77	5607
8	9751	1527	117	3160	4870	77	5607
9	10676	1527	117	3160	4870	1002	5607
10	13122	1527	117	3160	4870	3448	5607
11	22076	8991	117	3160	4870	4940	5607
12	23887	10800	117	3160	4870	4940	5607
13	28987	10800	117	3160	4870	9140	5607
14	29317	11400	117	3160	5500	9140	5607
15	31544	11400	117	3160	5500	11367	5607
16	32397	11400	970	3160	5500	11367	5607
17	32397	11400	970	3160	5500	11367	5607
18	32397	11400	970	3160	5500	11367	5607
19	32397	11400	970	3160	5500	11367	5607
20	26389	11400	3250	3160	5800	2779	0
Total Load	50093	10500	3130	4732	6738	22953	5953

Island Generated Load	23989
To be shed	26099

(All loads in kW)

D1	D2	D3	D4	D5
D6	D7	D8	D9	D10

Figure 3-5. Example accumulated load table display

4 Reacceleration

4.1 General

In case of faulty situations, such as bus undervoltage or load shedding, the loads are disconnected from the bus. The purpose of the function reacceleration is to determine which loads can be reconnected as soon as the network or parts of the network recovered from the undervoltage situation or the operator released the function reacceleration after load shedding by giving a general reset. Reacceleration for a substation in a substation node is realized with:

- *one type circuit for each substation*
- *one type circuit for each panelhalf in the substation*
- *one type circuit for each sheddable and reacceleratable load*

Reacceleration is executed in priorities and maximum disconnected times, defined in tables. The system determines which loads can be reaccelerated taking into account:

- *available island power*
- *priorities*
- *restart time*
- *network stability timer*

Any load shedding action, either primary or thermal load shedding or manual shedding, stops the execution of reacceleration.

4.2 Start of reacceleration

Reacceleration is initiated by undervoltage relays, at the busbar or the incoming feeders, of the concerning reacceleration groups or after reset of the load shed program.

Per island, the available nominal power is calculated. When reacceleration is activated, this available power is assigned to the substations proportional to the total load which can be reaccelerated in the substations.

Per substation this load value is calculated and sent down to the substation nodes, received by the **reacceleration substation** type circuit. With this load value and the priority load tables which are stored locally, the substation node reaccelerates loads per priority.

4.3 Distribution of available power

If in only one substation loads are switched off by undervoltage, all the available power in that island will be assigned to that substation.

4.4 Iterative reacceleration

To execute the reacceleration function as efficient as possible, the distribution of available power is executed in several 'power assignment' steps, thus making reacceleration an iterative process.

While the start-up load of most electric loads is much larger than the load in normal operation, it is possible that with the power that is assigned to the substation, only a few loads can be reaccelerated. After these few loads have been started up, the power consumption decreases to a fraction of the available power.

There will still be power available to start-up other loads. All substation nodes again access the amount of power that can be reaccelerated.

Next step

Each substation also sends a '*ready*' signal to the central node. If all ready signals are received, a next power distribution calculation is executed.

Reacceleration stops if all delay timers of the loads have expired, as indicated in the substation nodes. If reacceleration load from the substations equals zero and all ready bits are received, reacceleration is finished.

If loads have been shut-off by load shedding, reacceleration starts if a reset load shedding signal has been issued by the operator.

4.5 Interlockings

Reacceleration is blocked if there is any load shedding action at that moment or when reacceleration is inhibited by the operator.

After a definable shut-off time of the load, there will be no more automatic reacceleration for that load, it has to be restarted by the operator. This shut-off time can be defined for each load. Loads that were blocked or not running at the moment of undervoltage or load shedding will not be reaccelerated.

The calculation is started only in case an undervoltage was detected in any of the bus sections or in case primary load shedding shed loads.

4.6 Reacceleration sequencing

To avoid instabilities in the network due to reconnection of too many loads at the same time, the loads can be reaccelerated one by one. The time between starting two loads is then given as parameter for every load. This parameter can not be modified by the operator, but this can only be done with the help of an engineering tool.

The timer for every load gives the time before starting the next load is allowed.

5 Power Control

5.1 Active Power Control

5.1.1 General

The *“Active Power Control”* covers the system wide functions:

- *MW demand control*
- *Bus frequency control*
- *MW sharing control*

In these controls at least one machine is participating, but usually more than one machine is involved. For each machine an individual generator control type circuit is implemented, as described into chapter 6.

The active power control sends setpoints to each generator control module which is enabled to take part in that particular control action.

Whether it is possible to enable one of the above control modes, depends on the electrical network configuration which is determined by the *“Network Configuration Determination”* function.

5.1.2 MW demand control

Due to contractual obligations the active power exchange with the public power company (PPC) is optimized to an adjustable setpoint. There are usually two components which determine the amount to be paid to the PPC:

- *energy charge*
- *peak charge*

The MW demand control function has to ensure that the amount of imported power is kept at the desired setpoint, if possible with the available in-plant generation. The function also has to take care that contracted peak demand, in most cases measured as a sliding 15 minutes demand, is not exceeded.

Pulses obtained from the metering equipment at the exchange point with PPC are added over periods of 5 minutes and so represent the *actual* average power importation. In some cases exportation is allowed as well.

From the comparison between this measured importation (assuming importation only at this stage) and the requested setpoint for importation, the function calculates the increase or decrease of generation of the machines that are connected to PPC. After this it starts sharing the surplus or deficit of power to be generated amongst the machines. This sharing algorithm takes into account the control margin of the individual machines. The control margin is found by calculating the distance of the actual working point of the machine to the capability curve of the machine. The capability curve of every machine is modelled in the control module.

The capability is dynamic and depends for example on the ambient temperature, bus voltage and steam extraction.

A machine can only be enabled to take part in MW demand control if it is electrically connected to the public grid and the control mode of the machine should be MW mode. In case the connection to the public grid is lost or other disturbances occur the system will disable MW demand control for the concerned machines.

If the MW demand control function is not able to maintain the desired setpoint at the exchange point with PPC, for example because there is not enough steam available to reach the given setpoint, an audible alarm is created.

5.1.3 Bus frequency control

The bus frequency control function has the objective to maintain/re-establish the bus frequency at the desired frequency for a certain busbar or a combination of busbars in case the busbar or island is disconnected from the public grid. The latter especially in case the electrical load of the busbar is changing.

For every island only one machine can be the *“master of frequency”*. Frequency control could be done either be a separate controller which is enabled by the bus frequency function and receives it’s setpoint from this module, or directly by the generator control type circuit in the ABB Advant EMS and the machine running in droop mode. In the latter case the frequency is maintained sending raise/lower pulses to the governor.

Enabling frequency control for a machine is interlocked as long as the machine is connected to the public grid or to another machine which is the master of frequency. As soon as the frequency exceeds a high or a low limit an audible alarm is created.

5.1.4 MW sharing control

If two or more machines are operating in parallel in the same electrical network and this network is not connected to the public grid, one of the machines very often is operating in frequency or isochronous mode. The result of this is that the machine in frequency mode takes all the load changes in this particular island, while the other machines, which might run in MW mode, keep operating in the same working point. This could result in a situation where one machine is running very close to the limits of it’s capability curve while the other machines are running quite comfortably well within the limits of their capability curve. This should be avoided.

The MW sharing function re-calculates the working point of the machines connected in the concerned electrical network and for which MW sharing control is enabled. The re-calculation again is done by comparing the actual working point to the borders of the capability curve (control margin).

MW Sharing can only be enabled for the machines that are islandized from the grid. Alarms are created as soon as machines in MW sharing mode are operated too close to their respective capability curve.

5.1.5 MW setpoint control

5.1.5.1 MW demand control

Every 5 minutes a new MW setpoint is calculated for all machines participating in MW demand control. The local *"Generator Control"* function continuously checks if the generator working point still matches the calculated setpoint. If not, a control action is started immediately.

5.1.5.2 Isochronous control

Control is totally outside the ABB Advant EMS. The ABB Advant EMS activates or deactivates the external frequency controller.

5.1.5.3 Busfrequency control

The local *"Generator Control"* function continuously checks if the busfrequency matches the setpoint within the deadband. If not, a control action to adjust is started immediately. In this control mode raise/lower pulses are sent to the governor.

5.1.5.4 MW sharing control

Periodically, e.g. each minute, in isochronous control mode or bus frequency control mode of the machine operating in this control mode has drifted from the preferred setpoint. If so, a new working point for the in MW sharing operating machines is determined, based on the capability curve of each machine.

The *"Generator Control"* function of an in MW sharing control mode operating machine, periodically checks if the working point matches the setpoint within the deadband. If not, the control action to adjust is started immediately.

5.2 Reactive power control

5.2.1 General

The ABB Advant EMS has facilities to control the setpoint given to the controllers (AVR's) of the power generation units. The setpoints are given only if the system or the operator sets the AVR's control module of the involved power generation units in PF control mode.

The reactive power control function optimises the amount of reactive power exchanged with the PPC or follows a setpoint for the power factor. It does this by optimizing the reactive power generated by the power generation unit. The reactive power to be generated by these units is divided over the units according their possibility of taking more reactive load. In case the electrical plant network is in island operation the reactive power control function controls the voltage and gives the setpoint to the AVR.

The reactive power control function has the ability to calculate the capability curve of the units. From this capability curve the module determines how to divide the reactive power. This function covers the system wide functions:

- *PF demand control or Mvar control*
- *Voltage control*
- *Mvar sharing control*

In these controls at least one machine is participating, but usually more than one machine is involved. For each machine an individual generator control type circuit is implemented, as described in chapter 6.

The reactive power control module sends setpoints to each generator control that is taking part in that particular control action.

Whether it is possible to enable one of the above control modes, depends on the electrical network configuration which is determined by the *"Network Configuration Determination"*.

5.2.2 PF demand control

The PF demand control function offers the possibility to maintain an adjustable power factor setpoint at the exchange point with the public grid. The setpoint is usually determined by the contracted minimum power factor.

Depending on the contract with the public power company the algorithm is tuned. Often the decisive moment for the power factor is related to the maximum peak power demand in active power. Apart from the criteria given by the contract the operator has the opportunity to give a setpoint into the system. This allows to operate on the safe side.

Metering equipment at the exchange point with the public grid is used to obtain the actual Mvar values. An average value over i.e. the last 20 seconds is used to calculate the actual power factor value.

The deviation, the difference between the actual power factor and the setpoint, is input into the algorithm which shares the necessary surplus/shortage of reactive power over the generators.

The shortage or surplus in reactive power at the exchange point with the public grid is distributed over the participating generators according their control margin. The control margin of a generator is determined by the distance between the actual working point and the borders of the capability curve.

The calculations are made on a, tunable, cyclic basis. In case of a shortage of generation at the exchange point all connected generators in PF demand control mode are set to produce more reactive power. In case of a surplus at the exchange point the generators are set to produce less reactive power.

The function can only be activated if at least one generator is set for PF demand control. The PF demand control mode can only be activated for a generator if the generator is connected to the public grid and is running in PF mode.

A deadband is introduced to avoid unnecessary control actions.

The PF demand control mode has a lower priority than the MW demand control mode, this implies that when it is impossible to meet both setpoints, the MW setpoint has a higher priority, which could even mean that the PF-working point is controlled to a worse and lower power factor. If the PF demand control working point at the exchange point can not match the desired setpoint, within an adjustable time, an audible alarm is created.

If available in the electrical network, capacitor banks are taken in- and out of operation to meet the PF setpoint at the PPC exchange point.

5.2.3 Voltage control

The voltage control function has the objective the maintain the busvoltage at a desired level, even after major load changes.

In any electrical island only one generator can be set to control the voltage. Which generator is controlling the voltage in an electrical island is determined by the *"Network Configuration Determination"* function in conjunction with a pre-prepared table.

In electrical islands that are connected to the public grid the transformer voltage control takes care of the busvoltages.

If due to a change In the load of a busbar, the busvoltage follows the droop-line, the voltage control function in the generator module will start controlling the AVR up or down, when enabled for voltage control, until the desired voltage is achieved again.

This is a local control action and only active for the generator in voltage control mode.

A deadband is introduced to avoid unnecessary control actions. During a synchronizing action voltage control is frozen.

5.2.4 Mvar sharing control

If two or more machines are operating in parallel in the same electrical network, and this network is not connected to the public grid, one of the machines very often operates in voltage mode. The result of this is that the machine in voltage mode takes all the reactive load changes in this particular island, while the other machines which might run in Mvar control mode keep operating in their same working point. This could result in a situation where one machine is running very close to the limits of it's capability curve while the other machines are running quite comfortably well within the limits of their capability curve. This should be avoided.

The Mvar sharing control function re-calculates the working point of the machines connected in the concerned electrical network and for which the Mvar sharing control mode is enabled. The re-calculation is again done by comparing the actual working point to the borders of the capability curve (control margin).

Mvar sharing control mode can only be enabled for the machines that are islandized from the grid. Audible alarms are created as soon as machines in Mvar sharing control mode are operated too close to their respective capability curve.

5.2.5 Interlockings

The active participation in reactive power control for more reactive power is blocked if the voltage on the busbar can not be kept under a maximum value.

The active participation in reactive power control for less reactive power is blocked if the voltage on the busbar can not be kept above a minimum value.

Power factor setpoint changes, due to powerfactor control, are blocked if the generator is:

- *in local control*
- *disconnected from PPC*

5.2.6 PF setpoint control

5.2.6.1 PF demand control

All 5 minutes a new PF setpoint is calculated for all generators participating in PF demand control. The local *“Generator Control”* function continuously checks if the generator working point matches the calculated setpoint. If not, a control action is started immediately.

Calculation of the new setpoint is coordinated with the calculation of the MW setpoint if the MW demand control mode is active.

5.2.6.2 Voltage control

The local *“Generator Control”* function continuously checks if the busvoltage matches the setpoint within the deadband. If not, a control action to adjust is started immediately.

5.2.6.3 Mvar sharing control

Periodically, e.g. each minute, in voltage control mode the actual working point of the operating machine is verified to check whether is has drifted from the preferred setpoint. If so, a new working point for the in Mvar sharing operating machines is determined, based on the drift and the capability curves of the participating machines.

The *“Generator Control”* function of an in Mvar sharing control mode operating machine, continuously checks if the working point matches the setpoint within the deadband. If not, the control action to adjust is started immediately.

5.3 Auto sequencer

As the governor- and AVR control mode of a machine are subject to the network configuration the machine participates in, network configuration changes might need to change actual control modes. The *“Auto Sequencer”* function sends after a network configuration change, a message to all participating objects with the desired operating mode. These operating modes are stored in the table called *"Default Island Mode*

Settings" (DIMS). This table can be defined by the operator and has only a meaning for island configurations.

To be able to do so, the *"Auto Sequencer"* function continuously receives the actual electrical network configuration from the *"Network Configuration Determination"* function. The operator is always allowed to change the actual mode of an individual machine.

If the *"Auto Sequencer"* function changes a control mode of the governor or the AVR of one of the machines, an audible alarm is created.

5.4 Default island mode settings

To allow for easy mode changes, there are no interlocks between modes or mode changes in the DIMS table. However, for each island configuration an indication is created to warn the operator in case a setting in the DIMS results in an erroneous operation mode of the machines. The conditions for messages are restricted for the status of objects in one power station only.

There are no interlocks between the DIMS table setup and the actual control mode of the machine dialogue. After the setup in the DIMS table has changed, the operator has to verify that no warning exists. As long as a warning for a configuration exists, the setup for that configuration is not valid.

If the operator ignores the warning, the *"Auto Sequencer"* function will change the governor and/or AVR to the droop control mode if the warning is active at the very moment that configuration is detected.

A change according the DIMS table setup can be made at once for all machines of one powerhouse from a special DIMS table dialogue, or manual by selecting the individual machine concerned.

6 Generator control

6.1 General

For each machine in the electrical network, the *“Generator Control”* function is used. The *“Generator Control”* function is able to operate machines in different electrical network configurations, in island and in parallel.The *“Generator Control”* function is also able to cooperate with the *“Active Power Control”* and *“Reactive Power Control”* functions.

The *“Generator Control” function* is realized with:

- *one type circuit for the control of the governor and the AVR*
- *one type circuit for calculation and presentation of the capability diagram*

6.2 Control modes

6.2.1 General

For each machine a control mode can be selected for both governor and automatic voltage regulation (AVR) individually. The behaviour of the machine is subject to this control mode and to changes or fluctuations detected in the electrical network or steam system. Some control modes can be selected only in dedicated network configurations.

6.2.2 Governor control

6.2.2.1 Droop control

The generator is running in manual control, the adjustment of speed/frequency/power is operated from the central point of control by using the speed up/down keys. In the event of engine/generator failure, governor failure, breaker opened, local control or by command from the *“Auto Sequencer”* function, the control mode will automatically change to the droop control mode. Depending on the reason for switching to the droop control mode, audible alarms will be created. The actual MW value is transferred to the MW setpoint; this will give a bumpless switch over to another control mode.

6.2.2.2 MW control

The operator is able to give a MW setpoint to the generator, and the regulator will keep the generator at this value. After a new value is set, the setpoint will change slowly to the new value. If the generator can not follow the changes, an audible alarm is created. The setpoint will be set back to the actual value of the generator and start again changing the setpoint slowly to the new value.

The reason for not reaching the setpoint can be that the regulator is out of range, not having enough steam or fuel, or a generator is not connected to another generator on the grid, etc.

6.2.2.3 MW demand control

The MW demand control mode can only selected if the generator is already in MW control mode. The MW setpoint is now issued by the *“Active Power Control”* function, see also chapter 5. Before using this setpoint, the value must be valid.

An audible alarm is created and the generator will return into the MW control mode if:

- *the MW setpoint value is not valid within 10 minutes*
- *communication loss with the “Active Power Control” function, the mode will also be switched back to the MW Mode*

The output setpoint into the MW demand control mode acts the same as in MW control mode.

6.2.3 Automatic voltage control

6.2.3.1 Mvar control

The Mvar control mode is set automatically if the AVR fails. The voltage can be adjusted from central point of control by using the voltage up/down keys.

6.2.3.2 PF control

In the PF control mode the voltage/PF can be adjusted from central point of control by using the voltage up/down keys or by inserting a new value. The output setpoint is slowly changed to the new value. If the generator can not follow the setpoint, an audible alarm is created.

The output setpoint will be switched back to the actual value, and the program will try to reach the setpoint again. Reasons for not reaching the setpoint can be the excitor limits, or the generator is not connected with PPC or another generator, etc.

6.2.3.3 PF demand control

The PF demand control mode can only be activated if the generator is already in the PF control mode. The PF setpoint is now issued by the *“Reactive Power Control”* function, see also chapter 5.2. Before using this setpoint, the value must be valid. If the value is not valid within 10 minutes, an audible alarm is created.

An audible alarm is created and the AVR will return into the PF control mode if:

- *the PF setpoint value is not valid within 10 minutes*
- *communication loss with the “Reactive Power Control”*

The output setpoint into the PF demand control mode acts the same as in PF control mode.

6.3 Synchronization

The synchronization function implemented into the *"Generator Control"* function is started by selection of the generator breaker from central point of control. When synchronization is required, the generator name to use for the synchronization can be entered by the operator, whereafter the generator dialogue automatically will be presented and will be set into droop control mode. By selection of the synchronization command from the generator dialogue, the synchronization can be continued into manual or automatic mode. See also chapter 7.6.

6.4 Displays

In the single line diagram displays of the electrical network, the generators are only presented by the most important actual measured analogue data. Dedicated displays are available for more detailed generator information:

- *Generator overview*

  In this display, is In table format, detailed generator data is presented in a table regarding the actual control mode of the governor and the AVR, working setpoint and some alarms. It also offers, thanks to its layout, an overview of available modes for each generator individually.

- *Synchronization overview*

  In this display is the generator data included to complete and enable synchronization. It is not intended for mode- or setpoint control of the generator. For synchronization of the generator, this display can be consulted.

- *Capability diagram*

  The P-Q diagram of the generator includes:

  – *dynamic working point tracking*
  – *actual control mode, setpoint and working point*
  – *related analogue data*

- *Object display*

  In this display very detailed information is presented regarding the actual control mode of the governor and the AVR, related analogue data, working setpoint and all alarms.

6.5 Alarm- and event handling

- *general governor error*
- *governor setpoint error*
- *general AVR error*
- *governor AVR error*
- *command error*

- *digital- or analog signal error*
- *actual governor- and AVR control mode*

The remaining alarm- and event handling comply with the ABB AdvaCommand User Interface standard.

6.6 Operator dialogue control

Top level

D1 Governor mode...	D2 AVR mode...	D3 Direct Adjust-ment...	D4	D5 Block...
D6	D7	D8 Synchronization...	D9	D10 Keyboard...

Governor mode

D1 Governor Droop	D2 MW	D3 Frequency	D4	D5 Isochronous
D6 MW Peak	D7 MW Demand	D8 MW Sharing	D9	D10 Isochronous Backup

AVR mode

D1 AVR Droop	D2 PF	D3 Voltage	D4 Mvar	D5
D6	D7 PF Demand	D8 Mvar Sharing	D9 Mvar Demand	D10

Direct adjustment

D1 Speed ︾	D2 Speed ﹀	D3 Speed ︿	D4 Speed ︽	D5
D6 Voltage ︾	D7 Voltage ﹀	D8 Voltage ︿	D9 Voltage ︽	D10 Close

Block

D1	D2 Block Control	D3 Block Control	D4 Block Control	D5
D6 Interlock Bypass	D7 Block Control	D8 Block Control	D9 Block Control	D10 Reset Data

Synchronization

D1 Start Synchro	D2	D3 Test Synchro	D4	D5 Manual
D6 Stop Synchro	D7	D8	D9	D10 Close

Keyboard

D1	D2	D3	D4	D5
D6	D7 Acknowledge	D8 Object Display	D9	D10

6.7 Operator interface

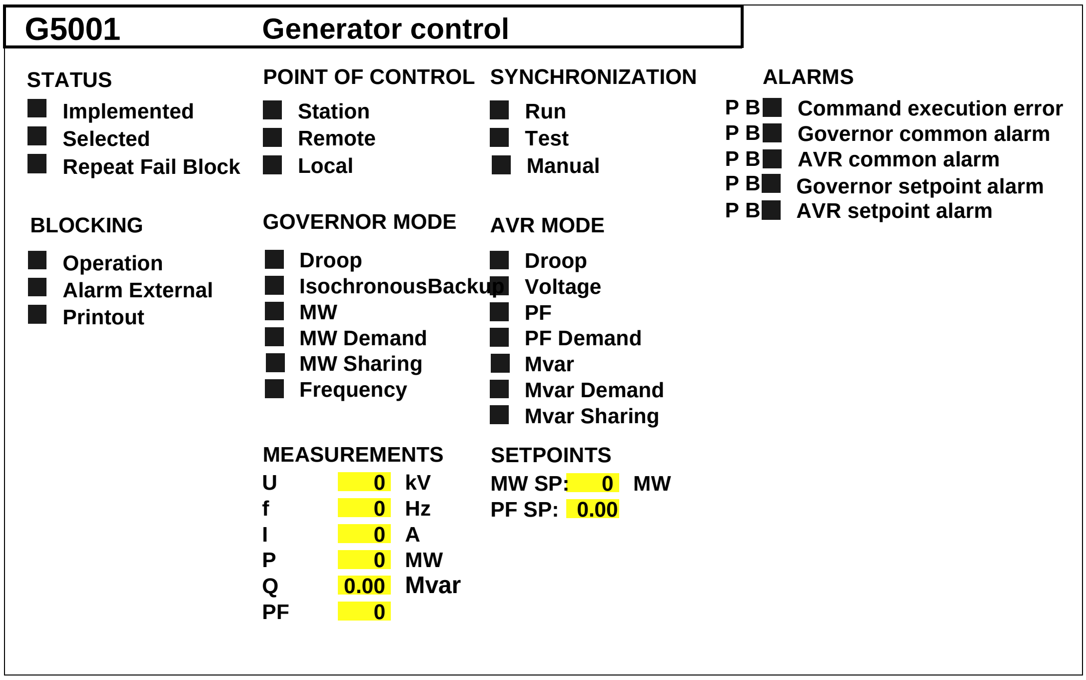


Figure 6-1. Object display of a generator

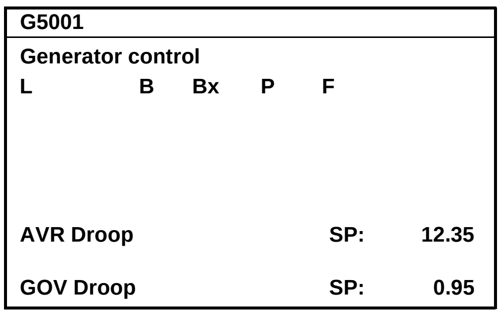


Figure 6-2. Small object close-up of a generator

Figure 6-3. Process display presentation of a generator

7 Breaker control

7.1 General

The breaker control is accomplished by three type circuits:

- *CBCNTRB0*

  Control of a single (synchronizing) breaker or disconnecter.

- *CBPANLB0*

  Control of two incoming feeders and one buscoupler breaker into a panel configuration.

- *CBMECAB0*

  Metering and calculation of quantities for the two above mentioned type circuits, which are controlled from the Advant Station 500 Series Operator Station.

The type circuits are consisting of a basic section and a number of optional additional functions. The basic section includes:

- *position conditioning and supervision*
- *command supervision*
- *support of different position limit switches*

7.2 Available options

The following options can be selected during instantiation of the type circuits:

- *control from the Advant Station 500 Series Operator Station and/or remote and/or local*
- *counting number of operations*
- *synchronization required*
- *load transfer function (CBPANLB0)*
- *opening breaker function (CBPANLB0)*

7.3 Point of control

The breaker control is used for one or more point of control:

- *Central*

  The breaker is controlled from the Advant Station 500 Series Operator Station.

- *Remote*

  The breaker is controlled from a remote desk or panel or an other process DCS system connected via a gateway or multi-vendor interface, such as MODBus.

- *Local*

  The breaker is controlled from a local desk or panel. The status conditioning and supervision are active. Control from central and remote point of control are blocked.

7.4 Control modes

For the panel configuration, each object has it's own control mode. This control mode is only valid for the optional "*Load transfer"* function:

- *Manual*

  The object will not be controlled by the load transfer function.

- *Auto*

  In the automatic control mode, the load transfer function is stand-by.

7.5 Automatic functions

Into the CBPANLB0 type circuit two automatic functions are optional:

- *load transfer*
- *opening breaker*

7.5.1 Load transfer

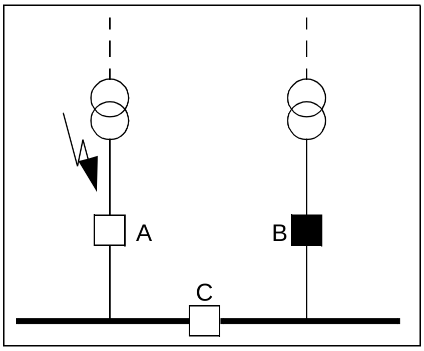
7.5.1.1 General

The load transfer function secures the electrical power supply to the loads connected to a busbar or part of a busbar which is not fed any more because the incoming feeder or the buscoupler breaker has been tripped by undervoltage.

When the central mode becomes active, the control mode value from the remote panel will be taken over, whereafter the operator can control the auto/manual control mode from the incoming feeders or buscoupler breaker dialogue.

The load transfer will be performed only into central mode by closing an incoming feeder or buscoupler breaker as soon as transfer conditions are met.

7.5.1.2 Example



Assume that the incoming feeder A is opened by a protection. When all conditions for the automatic transfer are met, buscoupler breaker C will be closed by the automatic transfer function

7.5.2 Opening breaker

The opening breaker function opens down stream one of the two incoming feeders or the buscoupler breaker after a tunable timeout, avoiding parallelism for a longer time. Which of the two incoming feeders or buscoupler breaker to open is chosen on forehand by the operator (default setting is the buscoupler breaker).

The opening breaker function is only active in central mode when all following conditions are met:

- *the two incoming feeders and buscoupler breaker are closed during a tunable time-out*
- *none of the two incoming feeders or buscoupler breaker is in the racked-out position*

7.6 Synchronization

The CBCNTRB0 type circuit offers the capability to synchronize automatically. The selection of the circuit breaker and the belonging generator is done by the operator from central point of control. Additional synchronization software determines which voltages should be applied to the synchronizer, whereafter relays are activated in such a manner that the correct voltages are actually applied to the synchronizer. The synchronizer will send the pulses raise/lower to the appropriate governor and the exciter again, by means of a relay circuitry that is controlled by the ABB ABB Advant EMS system. At the moment synchronism is reached, the synchronizer will release the close command. Assumed is that there is a synchrocheck relay available for each circuit breaker which is to be synchronized.

Also manual and semi-automatic synchronization is possible. In manual mode the operator has to give raise/lower commands from the central point of control and give a close command as soon as synchronism is reached. The close command has to be released by a synchrocheck function obviously. This synchrocheck function can be locally at the circuit breaker or be included in the synchronizer which is located in the central system. Manual synchronization can also be done from a dedicated panel if required.

In semi-automatic mode the raise/lower commands are given by the synchronizer but the actual closing command is still given by the operator from the central point of control. Again this command has to be validated by a synchrocheck functionality.

7.7 Interlockings

The breaker can be interlocked for operation by five separate signals from the process, of which one can be bypassed. Independent from the actual interlocking, operation of the breaker can be blocked at any time by the operator from the central control.

7.8 Alarm- and event handling

- *selection error*
- *operation command error*
- *limit switch error*
- *position error*
- *digital- or analog signal error*
- *protection trip*
- *spurious operation*
- *synchronization error*
- *automatic change over error*
- *automatic load transfer error*
- *operation count high limit*

The remaining alarm- and event handling comply with the ABB AdvaCommand User Interface standard.

7.9 Operator dialogue control

Top level

D1 Open	D2	D3 Synchronization...	D4 Auto	D5 Block...
D6 Close	D7	D8	D9 Manual	D10 Keyboard...

Block

D1	D2 Block Alarm	D3 Block Printout	D4 Block Control	D5
D6 Interlock Bypass	D7 Deblock Alarm	D8 Deblock Printout	D9 Delock Control	D10 Reset Data

Keyboard

D1	D2	D3	D4	D5
D6	D7 Acknowledge	D8 Object Display	D9	D10

7.10 Operator interface

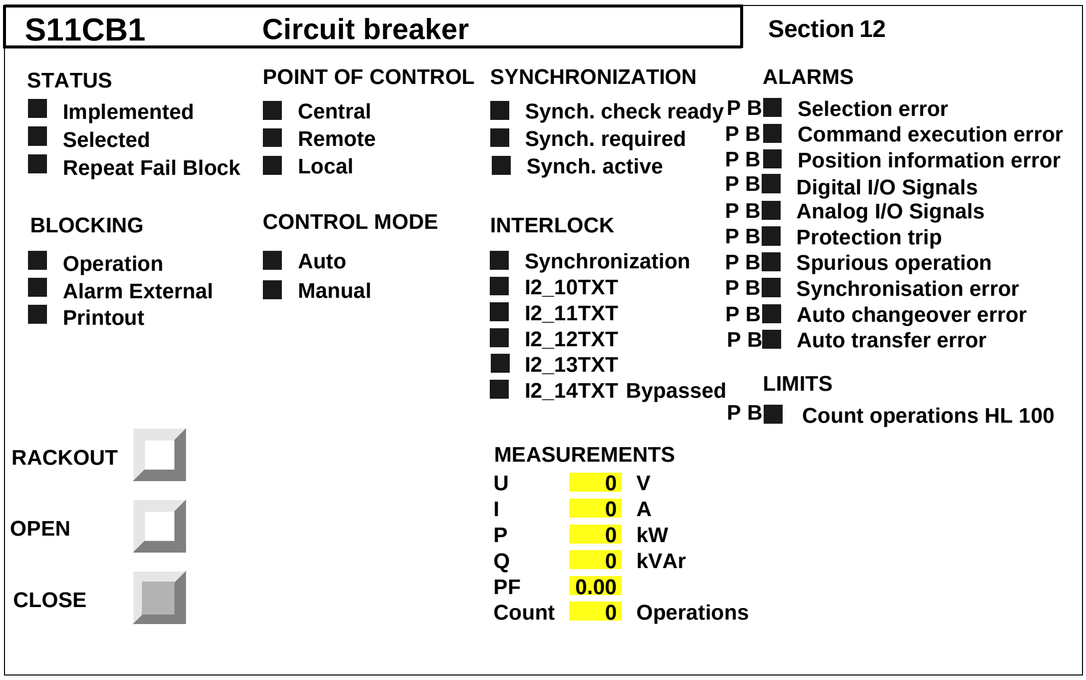


Figure 7-1. Object display of a breaker/disconnecter

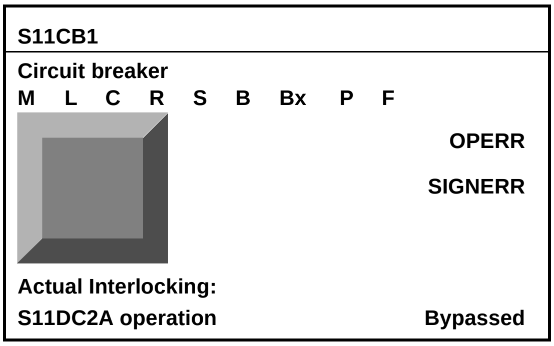


Figure 7-2. Small object close-up of a breaker/disconnecter

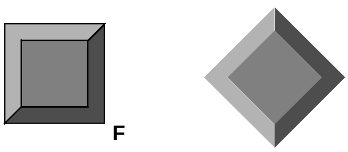


Figure 7-3. Process display presentation of breaker/disconnecter

8 Motor control

8.1 General

The motor control is accomplished by the MTCNTRB0 type circuit. The type circuit consists of a basic section and a number of optional additional functions. The basic section includes:

- *status conditioning and supervision*
- *command supervision*

8.2 Available options

The following options can be selected during instantiation of the type circuits:

- *control from the Advant Station 500 Series Operator Station and/or remote and/or local*
- *automatic start mode*
- *forward/backward control*
- *reacceleration*
- *load shedding*
- *running hours calculation*
- *motor type*

8.2.1 Load shedding

8.2.1.1 General

The load shedding function has to ensure at any time availability of electrical power to all essential and most of the critical loads in the plant. This is achieved by switching off non-essential loads in case of a lack of power in the plant electrical network, or parts of the electrical network.

In the load shedding functionality several priorities are used, within each priority also motorgroups can be assigned. A motorgroup is the smallest sheddable unit.

For each motor with the load shedding option, the operator from central point of control is able to:

- *change priority*
- *change group*
- *enable or disable load shedding*

8.2.2 Reacceleration

8.2.2.1 General

In case of faulty situations, such as bus undervoltage or load shedding, the motor can be disconnected from the bus by protection relays. The purpose of the function reacceleration is to determine which motors can be reconnected as soon as the network or parts of the network recovered from the undervoltage situation or the operator released the function reacceleration after load shedding by giving a general reset.

Reacceleration is executed in priorities and maximum disconnected times, defined in tables. The system determines which loads can be reaccelerated taking into account the available bus power, the priorities of the individual loads, the time past since the load was disconnected and the load values in case of reacceleration.

8.2.2.2 Conditions

Reacceleration of the motor is only possible if all of the below stated conditions are fulfilled:

- *motor has been running before load shedding or undervoltage took place*
- *reacceleration priority of the motor must be less than the reacceleration priority calculated by the system*
- *the reacceleration timer of the previous motor has been expired*
- *no load shedding active*
- *the motor is stopped*
- *no command error active*
- *motor not inhibited for reacceleration*
- *shut-off timer not elapsed*
- *bus voltage within pre-defined limits*
- *no protection activated any more*

8.2.2.3 Settings

The reacceleration settings stated below, can be changed by the operator from central point of control:

- *maximum shut-off time*
- *reacceleration priority*
- *inhibit or enable reacceleration*

8.3 Point of control

The motor control is used for one or more control modes:

- *Central*

  The motor is controlled from the Advant Station 500 Series Operator Station.

- *Remote*

  The motor is controlled from a remote desk or panel or an other process DCS system connected via a gateway or multi-vendor interface, such as MODBus.

- *Local*

  The motor is controlled from a local desk or panel. The status conditioning and supervision are active. Control from central and remote point of control are blocked.

8.4 Control modes

Each motor has it’s own optional control mode:

- *Auto start disabled*

  If the auto start control mode is disabled, the motor is not allowed to be started automatically.

- *Auto start enabled*

  If the auto start control mode is enabled, the motor is allowed to be started automatically.

8.5 Interlockings

The motor can be interlocked for operation by five separate signals from the process, from which one can be bypassed. Independent from the actual interlocking, operation of the motor can be blocked at any time by the operator from the central control.

8.6 Alarm- and event handling

- *operation command error*
- *limit switch error*
- *direction error*
- *digital- or analog signal error*
- *protection trip*
- *operation count high limit*
- *operated by load shedding*
- *reacceleration time-out*

The remaining alarm- and event handling comply with the ABB AdvaCommand User Interface standard.

8.7 Operator dialogue control

Top level

D1 Start	D2	D3 Backward	D4 Auto	D5 Block...
D6 Stop	D7	D8 Forward	D9 Manual	D10 Keyboard...

Block

D1	D2 Block Alarm	D3 Block Printout	D4 Block Control	D5
D6 Interlock Bypass	D7 Deblock Alarm	D8 Deblock Printout	D9 Deblock Control	D10 Reset Data

Keyboard

D1	D2	D3	D4	D5
D6	D7 Acknowledge	D8 Object Display	D9	D10

8.8 Operator interface

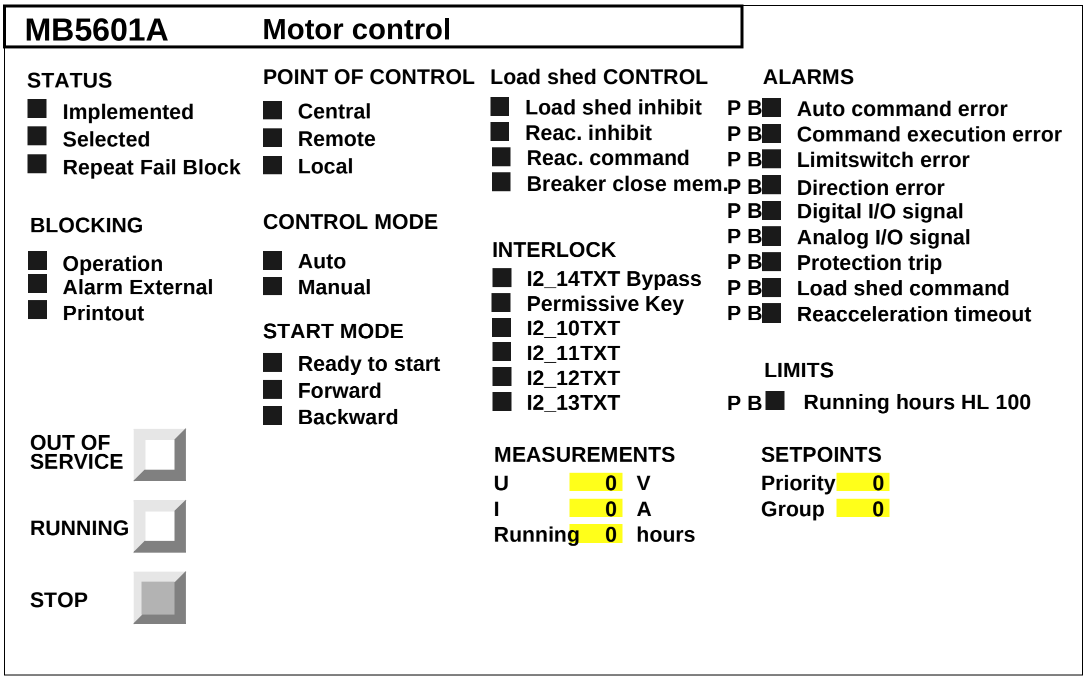


Figure 8-1. Object display of a motor

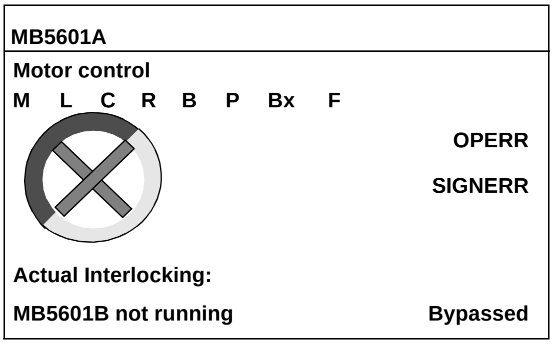


Figure 8-2. Small object close-up of a motor

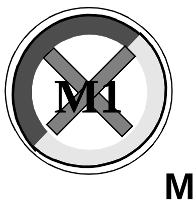


Figure 8-3. Process display presentation of a motor

9 Transformer Control

9.1 General

The transformer control is accomplished by four type circuits:

- *TRCNTRB0*

  Used for control of one transformer, equipped with an on-load tap changer and controlled under master-slave conditions for parallel operation, located into a different Advant Controller as the concurrent transformer.

- *TRCNTRB1*

  Used for control of two transformers, both equipped with on-load tap changers and controlled under master-slave conditions for parallel operation.

- *TRCNTRB2*

  Used for control of one stand-alone transformer, equipped with an on-load tap changer.

- *TRMECAB0*

  Metering and calculation of quantities for the three above mentioned type circuits, which are controlled from the Advant Station 500 Series Operator Station.

The first three type circuits are consisting of a basic section and a number of optional additional functions. The basic section includes:

- *control from the Advant Station 500 Series Operator Station*
- *status conditioning and supervision*
- *command supervision*

9.2 Available options

The following options can be selected during instantiation of the type circuits:

- *remote point of control and/or local point of control*
- *count number of tap changer operations*

9.3 Point of control

The transformer point of control:

- *Central*

  Transformer is controlled from the Advant Station 500 Series Operator Station.

- *Remote*

  Transformer is controlled from a remote desk or panel or an other process DCS system connected via a gateway or multi-vendor interface, such as MODBus.

- *Local*

  Transformer is controlled from a local desk or panel. The status conditioning and supervision are active. Control of transformer from central point of control and from remote point of control is blocked and the control mode will be forced to independent manual control.

9.4 Control modes master/slave

This chapter describes the control modes available for master/slave control implemented by the type circuits TRCNTRB0 and TRCNTRB1. The control modes for the stand-alone control implemented by the type circuit TRCNTRB2 are described into chapter 9.5.

9.4.1 Master control mode

One of the transformers is defined as master, the other transformer is defined as slave. The slave transformer follows the lower and raise commands for the tap position of the master transformer. The operator can activate the master control mode under certain conditions. The type circuit can not force the master control mode. When the master control mode is active, one of the below stated control modes can be activated:

- *master manual control*
- *master auto control*

9.4.1.1 Master manual control

For master manual control, the voltage control of both transformers is dependent from each other. The master transformer voltage control can be defined by manual control, from central- and/or remote point of control, by lower and raise tap position commands. The slave transformer follows the lower and raise commands for the tap position of the master transformer. When a transformer is defined as slave transformer, the active control mode can not be changed by the operator from the slave transformer.

The operator can only activate the master manual control mode for the transformer when all the conditions are fulfilled.

9.4.1.2 Master auto control

For master auto control, the voltage control of both transformers is dependent from each other. The master transformer voltage control is defined by the difference of the actual tap position and a calculated tap position of the transformer defined as master.

The difference between the actual tap position and the calculated tap position for the master transformer, will result into lower and raise tap position commands. The slave transformer follows the lower and raise commands for the tap position of the master transformer. When the transformer is defined as slave transformer, the active control mode can not be changed by the operator of the slave transformer.

The operator can only activate the master auto control mode for the transformer when all the conditions are fulfilled.

9.4.2 Independent control mode

For independent control, the master-slave relation is stopped, meaning that both transformers are controlled independent from each other. The operator can activate the independent control mode at any time, but can also be forced by the type circuit. When the independent control mode is active, one of the below stated control modes can be activated:

- *independent auto control*
- *independent manual control*

The type circuit will activate the independent control mode for the transformer when the transformer is defined as master, and the master release is not valid any more.

9.4.2.1 Independent manual control

For independent manual control, the transformer voltage is controlled by the operator by raise/lower commands. When the independent control mode is active, the operator can always activate the independent manual control mode.

In the independent manual control mode the raise and lower commands are blocked when the actual tap position is equal to respectively the highest and lowest tap position possible.

The type circuit will activate the independent manual control mode for the transformer, when one of the conditions stated below are fulfilled:

- *local point of control is active*
- *the master release is not valid any more*
- *an I/O error, only when not defined as slave*
- *a tap position error*
- *manual forced*
- *not connected to the grid, only when not defined as slave*
- *a command error*

When the transformers is set into independent manual control by the type circuit, it will also activate the independent control mode for the other transformer.

9.4.2.2 Independent auto control

For independent auto control, the voltage control is defined by the difference of the actual tap position and a calculated tap position of the transformer. The difference between the actual tap position and the calculated tap position for the transformer, will result in lower and raise tap position commands.

The operator can only activate the independent auto control mode when all the conditions are fulfilled:

9.5 Control modes stand-alone

9.5.1 Manual control

For manual control, the transformer voltage is controlled by the operator by raise/lower commands. The operator can always activate the manual control mode. In the manual control mode the raise and lower commands are blocked when the actual tap position is equal to respectively the highest and lowest tap position possible.

The type circuit will activate the manual control mode for the transformer, when one of the conditions stated below are fulfilled:

- *local point of control is active*
- *an I/O error*
- *a tap position error*
- *manual forced*
- *a command error*

9.5.2 Auto control

For auto control, the voltage control is defined by the difference of the actual tap position and a calculated tap position of the transformer. The difference between the actual tap position and the calculated tap position for the transformer, will result into lower and raise tap position commands.

The operator can activate the independent auto control mode when the transformer is not forced into manual control.

9.6 Manual trip

A manual trip command is only possible from central point of control when the tap changer is moving.

9.7 Interlockings

The transformer can be interlocked for operation by signals from the process. An interlocking is active if one of below stated conditions is fulfilled:

- *blocked for operation by the operator*
- *no interlock release*
- *the actual tap position is equal to respectively the highest and lowest tap position possible*

9.8 Alarm- and event handling

- *local control*
- *operation command error*
- *tap changer position error*
- *independent manual control*
- *digital- or analog signal error*
- *protection trip*
- *manual trip*
- *operation count high limit*

The remaining alarm- and event handling comply with the ABB AdvaCommand User Interface standard.

9.9 Operator dialogue control

Top level

D1	D2	D3 OLTC Trip	D4 Auto	D5 Block...
D6 Independent	D7 Master	D8	D9 Manual...	D10 Keyboard...

Block

D1	D2 Block Control	D3 Block Control	D4 Block Control	D5
D6 Interlock Bypass	D7 Block Control	D8 Block Control	D9 Block Control	D10 Reset Data

Manual

D1	D2	D3	D4	D5
D6 Lower	D7	D8	D9	D10 Raise

Keyboard

D1	D2	D3	D4	D5
D6	D7	D8 Object Display	D9 Object Trend	D10

9.10 Operator interface

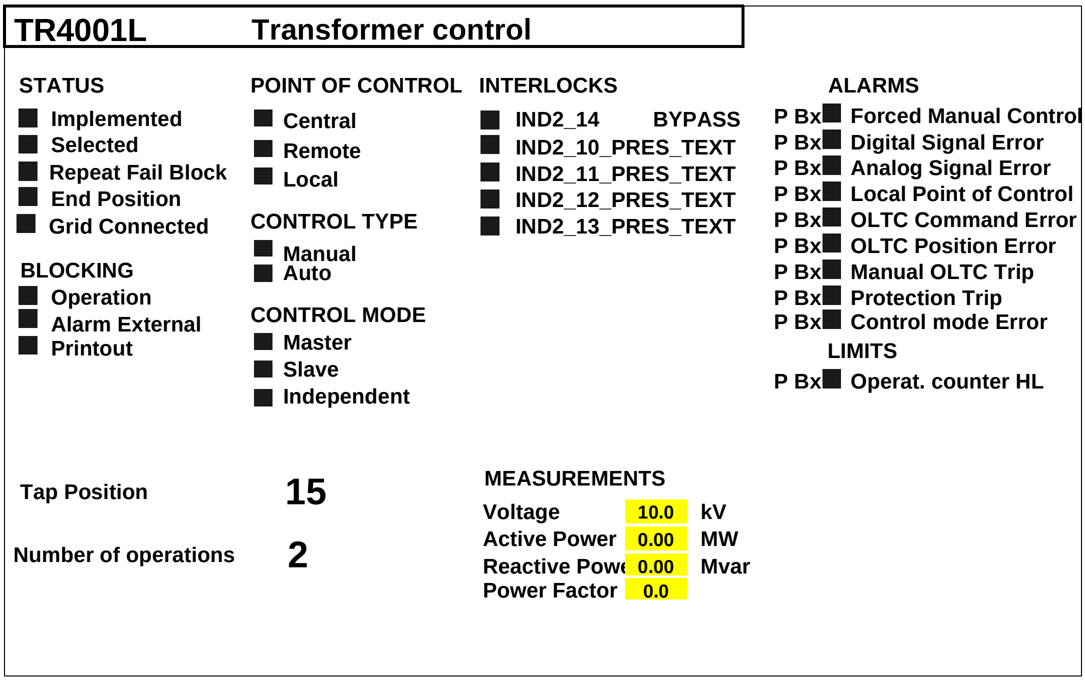


Figure 9-1. Object display of a transformer

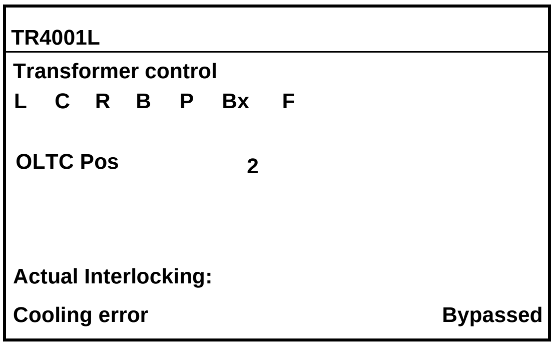


Figure 9-2. Small object close-up of a transformer

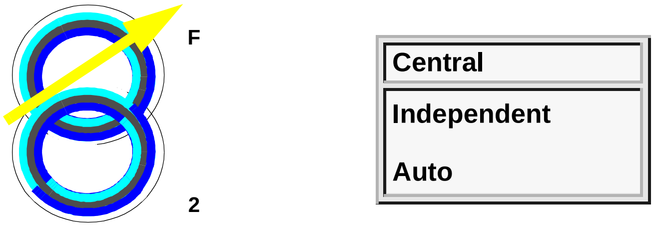


Figure 9-3. Process display presentation of a transformer