

TECHNICAL REPORT

IEC TR 62140-1

First edition
2002-10

Fossil-fired steam power stations –

Part 1: Limiting controls

Centrales à vapeur consommant des combustibles fossiles –

*Partie 1:
Régulations de limitation*



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International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch



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CONTENTS

FOREWORD	5
INTRODUCTION	7
1 Scope	8
2 Terms, subscripts and abbreviations	8
2.1 Notations	8
2.2 Subscripts	9
2.3 Abbreviations (also used as subscripts)	9
3 Function of limiting controls	10
3.1 Values to be limited	11
3.2 Functional modules for limiting	11
4 List of limiting controls	11
Annex A Upper limiting of steam pressure of steam generators	16
A.1 Task	16
A.2 Description of the control structure	17
A.3 Operating behaviour	18
A.4 Supplementary information	19
Annex B Lower limiting of steam pressure of steam generators	20
B.1 Task	20
B.2 Description of the control structure	21
B.3 Operating behaviour	22
B.4 Supplementary information	22
Annex C Limiting control of thermal stresses in pressure-bearing components	23
C.1 Task	23
C.2 Description of the control structure	23
C.3 Operating behaviour	26
Annex D Lower limiting of evaporator flow for once-through boilers	27
D.1 Task	27
D.2 Description of the control structure	27
D.3 Operating behaviour	32
Annex E Limiting controls on the feed-water function group	36
E.1 Task	36
E.2 Description of the control structure	39
E.3 Operating behaviour	40
E.4 Further control structures	44

Annex F Lower limiting of furnace thermal output, using as an example direct-firing pulverized coal furnace	46
F.1 Task.....	46
F.2 Description of the control structure.....	49
F.3 Operating behaviour.....	49
Annex G Permissible turbine thermal stresses	51
G.1 Task.....	51
G.2 Description of the control systems.....	51
G.3 Operating behaviour.....	53
G.4 Supplementary information	53
Index.....	54
Figure 1 – Change in a controlled variable over time	10
Figure A.1 – Plant circuit diagram for upper steam pressure limiting control using bypass devices	16
Figure A.2 – Pressure characteristics of a conventional power station unit, shown for modified sliding pressure	17
Figure A.3 – Function plan of master control of a steam bypass device for conventional power stations	18
Figure B.1 – Plant circuit diagram for lower steam pressure limiting control	20
Figure B.2 – Pressure characteristics of a conventional power station unit, shown for modified sliding pressure	21
Figure B.3 – Function plan of master control of a high-pressure minimum pressure control for conventional power stations	22
Figure C.1 – Data logging, calculation, display; documentation of a limiting control.....	24
Figure C.2 – Set-point guidance of steam temperature.....	25
Figure D.1 – Start-up system for start-up low power operation	28
Figure D.2 – Feed-water control with circulating pump in main flow (Table D.1 b)	29
Figure D.3 – Feed-water control with circulating pump in bypass flow (Table D.1 c).....	30
Figure D.4 – Feed-water control with circulating via feed-water pump (Table D.1 d).....	31
Figure D.5 – Limiting of evaporator flow during load increase.....	33
Figure D.6 – Limiting of evaporator flow during shut-down	34
Figure E.1 – Plant overview of feed-water function group	38
Figure E.2 – Feed-water pump characteristics with limit curves.....	39
Figure E.3 – Simplified function plan of a feed-water control with limiting and structure shift	42
Figure E.4 – General plan of feed-water control with speed-controlled E-pump and low power control valve	43
Figure F.1– Plant connection diagram of a milling unit	47
Figure F.2 – General plan of limiting control of minimum furnace thermal power	48
Figure F.3 – Example of start-up of a milling unit with oil support. Oil ignition power (for ignition coal) minimum oil power. The furnace thermal output of the steam generator is met using other burner groups.	50

Figure F.4 – Example of shut-down of a milling unit. The minimum furnace thermal output of the steam generator is met using other burner groups	50
Figure G.1 – Formation of stress allowance	52
Table 1 – List of limiting controls	12
Table D.1	32
Table E.2	40
Table E.2	44

INTERNATIONAL ELECTROTECHNICAL COMMISSION

FOSSIL-FIRED STEAM POWER STATIONS –

Part 1: Limiting controls

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC 62140-1, which is a Technical Report, has been prepared by IEC technical committee 65: Industrial-process measurement and control.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
65/271/CDV	65/283/RVC

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the IEC/ISO Directives, Part 2.

IEC 62140 consists of the following parts, under the general title *Fossil-fired steam power stations*:

Part 1: Limiting controls

Part 2: Drum-level control

Part 3: Steam-temperature control

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this Technical Report may be issued at a later date.

INTRODUCTION

This Technical Report is part of a series of Technical Reports which contain advice on the proper design and operation of control circuits in fossil-fired power stations. They are based on technical solutions used today by some member nations and provide also the background information necessary for proper understanding.

For the time being, all the different national documents tackling the subject are deemed to be at the same level. They always present or imply particular technical solutions which, although finally aimed at satisfying similar functional user needs, are different from country to country and often inconsistent among themselves. Such documents are considered to be real barriers to international trade.

The need for new standards formalizing an internationally agreed approach to express the functional need of fossil-fired power plant operators and suppliers is clearly identified by all the experts. Such documents could facilitate and develop the international business in this particular domain for the profit of the suppliers and the customers. The IEC 62140 series should consider the existing national documents presenting national solutions as a technical basis and should be consistent with them.

In the absence of an internationally agreed approach, this Technical Report is to be strictly considered as an example of particular technical solutions at a given time. It is only aimed at stimulating the debate in order to encourage the convergence of views on the subject and should not be transformed into an International Standard.

There are two types of technical reports within this series.

The reports of the first type refer to specific control circuits of steam generators, such as drum-level control or steam-temperature control and that under normal operational conditions.

The reports of the second type show special means to ensure proper operation also under restricted conditions, for example, during run-up and run-down or in the event of anomalous operating states, or they deal with super-ordinated control circuits, for example, load control or frequency control systems. These reports refer generally to the power station unit as a whole.

Each of the reports within this series is independent from each other; their contents, however, are largely coordinated. The series is to be supplemented.

FOSSIL-FIRED STEAM POWER STATIONS –

Part 1: Limiting controls

1 Scope

This Technical Report deals with limiting controls in fossil-fired steam power stations.

In their task and effect, limiting controls lie between the actual operating controls and the protective devices. Operating controls have the task of controlling the power generation process in such a way that the generated output always corresponds to the predetermined set point, and the individual subprocesses are thus carried out in accordance with economic and environmental criteria. Protective devices have the task of protecting human beings, the environment and the plant as well as its components against damage, principally by means of shut-down. Limiting controls are used to support the operating controls, and hence enable continued operation – possibly under restricted conditions – in the event of transient processes, for example, during start-up and shut-down, and in the event of anomalous operating states.

Limiting controls frequently make use of the actuators of the operating controls. They can be switched off in the same way as the operating controls. When they are switched off, however, the possibility no longer exists of early and automatic limiting of process values before the protective device is triggered. The limiting controls thus differ from the protective devices, which cannot be switched off and which mostly function with their own actuators. Operating controls and protective devices are not dealt with in this report.

The tasks for control of subprocesses may vary as a function of the operating state of the whole plant. Structure shifts are carried out to adapt the control to the various tasks. These are devices used to select structures

- between operating and limiting controls;
- within limiting controls;
- within operating controls.

Structure shifts are thus not independent control solutions to process tasks. They are dealt with in this Technical Report in connection with the limiting controls (see examples in Annexes A to G).

2 Terms, subscripts and abbreviations

2.1 Notations

$\dot{m}$	mass
m	mass flow, mass throughput
n	speed
p	pressure
$\dot{p}$	speed of pressure change
Δp	differential pressure
P	power
Q	quantity of heat
$\dot{Q}$	heat flux
t	time
ϑ	temperature

$\Delta\vartheta$	differential temperature
σ	material stress
e	control error
w	reference variable
x	controlled variable

2.2 Subscripts

ex	external
op	operation, operating
el	electrical
i	internal, inner (inner wall temperature)
m	mean (mean wall temperature)
act	actual value
max	maximum
c	centre
min	minimum
ref	reference
sp	set point
target	target
perm	permissible
uL	upper limit
lL	lower limit

2.3 Abbreviations (also used as subscripts)

O	outlet
F	fuel
SG	steam generator
I	inlet
ECO	economizer
D	delivery (for example, p_D – delivery pressure)
LS	live steam (main steam)
L	limit value
HP	high pressure
K	constant
IP	intermedium pressure
LP	low pressure
FWT	feed-water tank
FWP	feed-water pump
FW	feed water
C	circulation
E	evaporator
W	reference variable
RH	reheater
HRH	hot side of reheater
SPG	set-point guidance
HPO	high-pressure outlet

3 Function of limiting controls

The function of operating control and its relief by a limiting control is shown by way of example in Figure 1 using the change in a process variable (controlled variable) over time.

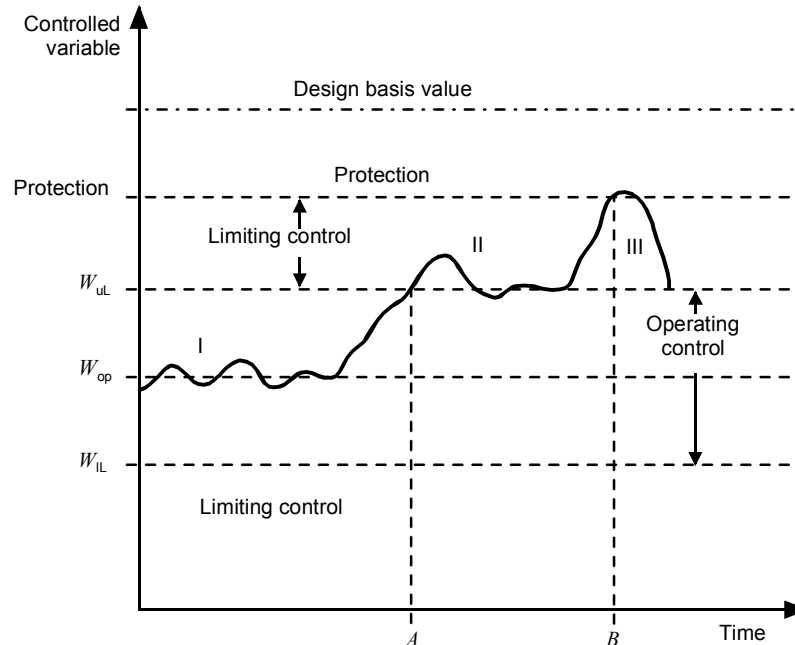


Figure 1 – Change in a controlled variable over time

Area I: The effects of faults of the plant, of a part of it or of the process are kept within the permissible limits by the operating control. The controlled variable is returned to the operating set point W_{op} .

Area II: The effects of faults can no longer be controlled by the operating controls: at time A , the limiting control intervenes and returns the controlled variable to a set point W_{UL} (upper limit value) or W_{IL} (lower-limit value), which deviates from the set point of the operating control. The control task may be transferred back to operating control

- by adjusting the set points, or
- by bringing the controlled variable closer to the operating set point.

This can be done manually or automatically.

Area III: The process fault leads to a change in the controlled variable which can be checked neither by the normal operating control nor by the limiting control. At time B , the protection intervenes, safely preventing the design basis value from being reached.

3.1 Values to be limited

Depending on the requirements of the process and its components, the following values may have to be limited:

- variables of state;
- their derivations and suchlike;
- the result of combinations of individual process variables.

This is done by specific limiting of

- reference variables;
- controlled variables;
- manipulated variables

of the operating control circuits.

The implementation of independent control circuits for limiting purposes is a further possibility.

3.2 Functional modules for limiting

As listed in 3.1, the limiting intervention can be carried out using two different methods.

a) Intervention directly into the structure of operating control.

This can be carried out by means of the following:

- switches which are triggered via a separate logic and hence change the control structure
 - by activating the limiting variable instead of the normal controlled variable,
 - by holding ramp rates,
 - by freezing integral action
- selection circuits comprising combinations of extremity selector modules (MIN, MAX).

b) Implementation of a separate control circuit

Data logging, controller and actuator are constructed independently and separately from the operating control. In this case, intervention is carried out directly into the process, and not by means of switching or selecting operating control signals.

4 List of limiting controls

Limiting controls which are important for the power station unit are listed below. In accordance with the construction of the individual function groups of the power station, only a part of these limiting controls is required; otherwise, additional limiting controls – which are not stated here – are to be provided for.

The most important limiting controls are listed in Table 1, and some selected examples are described in comprehensive fashion in Annexes A to G. The selection is made according to the importance and complexity of the control task.

Table 1 – List of limiting controls

Function group	Task	Control structure			Operating behaviour during			Additional comments
		Controlled variable	Reference variable	Manipulated variable	Start-up	Shut-down	Power change	
HP bypass device	Upper limiting of HP steam pressure	HP steam pressure	Maximum operational HP steam pressure (dependent on steam flow)	Position of the HP bypass valves	Not operative	Operative	Operative	Malfunction may lead to actuation of the safety valves or of special, additional devices of the HP bypass device. These additional devices of the HP bypass device lead to rapid opening and may thus take the place of the HP safety valves. Water injection to adjust the steam temperature behind the bypass device is necessary See Annex A for further details
HP pressure system	Lower limiting of HP steam pressure	HP steam pressure	Minimum required operational HP steam pressure (dependent on steam flow)	Position of the HP control valves of the turbine	Operative	Not operative	Operative	The HP minimum pressure control can also be used as an HP initial pressure control by switching over the reference variable with the speed/power control disengaged See Annex B for further details
Set-point guidance unit power	Limiting thermal stress in pressure-bearing components	Wall-temperature difference $\Delta \vartheta$ component σ thermal stress	Permissible wall-temperature difference perm $\Delta \vartheta$ component σ_{perm}	Feed-water flow, injection water flow, steam flow, fuel flow	Operative	Operative	Operative	Malfunction leads to premature material exhaustion and hence to lifetime losses. Special interlocks and protective shut-downs are not required for the steam generator See Annex C for further details
Feed water	Limiting evaporator flow to minimum value (lower limit value)	Evaporator (feed-water flow before ECO)	Required minimum evaporator flow	a) Feed-water pump speed (normal operation) b) Throttling with feed-water control valve (low power operation)	Operative	Operative	Operative (in re-circulation operation)	Malfunction may lead to unequal flow through and cooling of the parallel evaporator tubes, and thus to damage to the tubes Only required with forced flow steam generators. See Annexes D and E (E.1.5) for further details.

Function group	Task	Control structure			Operating behaviour during			Additional comments
		Controlled variable	Reference variable	Manipulated variable	Start-up	Shut-down	Power change	
Feed water	Limiting rate of pressure drop in the feed-water tank	Rate of pressure change in the feed-water tank	Permissible rate of pressure drop	Feed-water pump speed	Not operative	Operative (in very rapid shut-down)	Operative (in very rapid power reductions)	Malfunction may lead to damages to the feed-water pump (flashing in the suction pipe). In general, only required for exceptional operating states, for example, when sufficient vapour plating of the deaerator is not guaranteed See Annex E (E.1.4) for further details
Feed water	Limiting pressure in the feed-water header to a maximum value	Pressure in the feed-water header	Permissible maximum pressure	Feed-water pump speed	Not operative	Not operative	Operative in exceptional cases	Malfunction may lead to pipe damage See Annex E (E.1.7) for further details
Feed water	Limiting the differential pressure between the pump pressure and the HP steam-outlet pressure to a minimum value	Feed-water pump exit pressure	HP steam outlet pressure plus preset minimum differential pressure	a) Throttling with feed-water control valve (normal operation) b) Feed-water pump speed (low power operation)	Operative in exceptional cases	Operative in exceptional cases	Operative in exceptional cases	Malfunction may, particularly with natural circulation steam generators, lead to various feed-water pump extraction pressure or the injection water pressure being too low in certain operating cases See Annex E (E.1.6) for further details
Feed water	Preventing the feed-water flow to the evaporator from deviating from the guide value to an excessive degree during start-up and shut-down or pump change-over	Control error of feed-water pump controller, controlling at the time	Zero	Feed-water pump speed of the pump being start-up or down The transient of speed regulation is affected	Operative	Operative	Operative	Malfunction leads to over- or underfeed to the steam generator See Annex E (E.1.8) for further details.
Feed-water pump	Limiting the feed-water pump delivery to a minimum value	Feed-water pump delivery	Required minimum delivery	Reflux to the feed-water tank by opening the normally closed minimum flow valve	Operative	Operative	Not operative	Malfunction may lead to damage of the feed-water pump (for example, overheating) Limiting control is designed both as a control and as a continuous control See Annex E (E.1.1) for further details

Function group	Task	Control structure			Operating behaviour during			Additional comments
		Controlled variable	Reference variable	Manipulated variable	Start-up	Shut-down	Power change	
Feed-water pump	Limiting feed-water pump outlet pressure to a minimum value derived from the delivery flow	Feed-water pump outlet pressure	Function derived from delivery flow	Throttling with feed-water control valve	Operative	Operative	Operative in sliding pressure operation depending on design (for example, with half-load pumps)	Malfunction may lead to non-permissible axial loading of the feed-water pump (protective actuation) due to excessively low dynamic pressure compensation See Annex E (E.1.2) for further details (Figure E.3)
Feed-water pump	Limiting feed-water pump outlet pressure to a minimum value in accordance with the limit curve	Feed-water pump delivery flow	Control limit curve derived from feed-water pump pressure	a) Feed-water pump speed b) Feed-water control valve when minimum pump speed reached	Operative	Operative	Operative in sliding pressure operation depending on design (for example, with half-load pumps)	Malfunction may lead to non-permissible axial loading of the feed-water pump due to excessively low dynamic pressure compensation See Annex E (Clause E.4) for further details (Figure E.4)
Feed-water pump	Limiting feed-water pump outlet pressure to a minimum value	Feed-water pump outlet pressure	Preset minimum delivery pressure	a) Throttling by feed-water control valve (normal operation) b) Feed-water pump speed (low power operation)	Operative	Operative	Operative in sliding pressure operation depending on design (for example, with half-load pumps)	Malfunction may lead to wearing of the pump See Annex E (E.1.3) for further details
Fuel	Preventing the furnace thermal power of the steam generator burners from falling below a minimum value	Sum of fuel flow (furnace thermal power of steam generator)	Minimum furnace thermal power of the steam generator	fuel reference variables from feeder speed controller	Not operative	Not operative	Operative	See Annex F for further details
Fuel	Preventing the furnace thermal power of the burner group of a milling unit from falling below a minimum value	Fuel flow of the burner group of a milling unit	Minimum furnace thermal output of the burner group of a milling unit	Burner group controller position of speed divider device or control valve	Not operative	Not operative	Operative	See Annex F for further details

Function group	Task	Control structure			Operating behaviour during			Additional comments
		Controlled variable	Reference variable	Manipulated variable	Start-up	Shut-down	Power change	
LP bypass device	Upper limiting of RH steam pressure	RH steam pressure	Maximum operational RH steam pressure (load dependent)	Position of LP bypass valves	Not operative	Operative	Operative	To reduce the steam temperature, water may be sprayed into the bypass steam before it enters the condenser. The LP bypass device is subject to superimposed interlock which is able to bring about partial or complete closure of the bypass valve combination. The device is therefore unable to take on a safety-valve function
Turbo-generator group	Limiting of the minimum output of the turbogenerator	Generator output	Minimum generator output	Intervention occurs via the power set point of the turbine and thus on turbine inlet valves/steam flow	Operative	Operative	Operative	Malfunction lead via motoring to opening of the generator switch; in individual cases, this may lead to turbogenerator set trip
Turbine	Preventing turbine overspeed	Turbine speed	Maximum permissible speed (1,5 % below trip speed; this corresponds to ca. 108,5 % of nominal speed)	Intervention occurs via turbine inlet valves (HP part) and interceptor valves (IP part) steam flow	Operative	Operative	Operative	Malfunction may lead to turbogenerator set trip Acceleration limiting is provided to improve the intercept safety of the turbines
Turbine	Limiting thermal stress in turbine shaft/housing	$\Delta \vartheta$ component as a measure of thermal stress σ	Permissible stress σ_{perm}	Position of the live steam control valves and interceptor control valves	Operative	Operative	Operative	Malfunction may lead to turbogenerator set trip See Annex G for further details
IP proportional pressure control	Lower limiting of IP turbine exhaust steam pressure of extraction turbines	IP turbine exhaust steam pressure	Maximum pressure ratio from steam pressure in front of and behind IP turbine blading	Position of LP control valves in the crossover pipes to the LP turbine	Operative	Operative	Operative	The LP control valve is controlled by a minimum selection from the turbine control/extraction control

Annex A

Upper limiting of steam pressure of steam generators

A.1 Task

During shut-down of the unit and during normal operation, changes may occur in the high pressure and reheater pressure in the event of deviations between the generated steam flow and the steam flow taken up by the turbine. If a high pressure occurs which exceeds the preset upper limiting characteristic of the plant, the steam flow which is not taken up by the turbine is led off to the condenser. The latter can be carried out via the high-pressure bypass device if present, either directly to the condenser in the case of plants without reheaters, or, in the case of plants with reheaters, to the reheater first and from there to the condenser. Figure A.1 shows an elementary diagram.

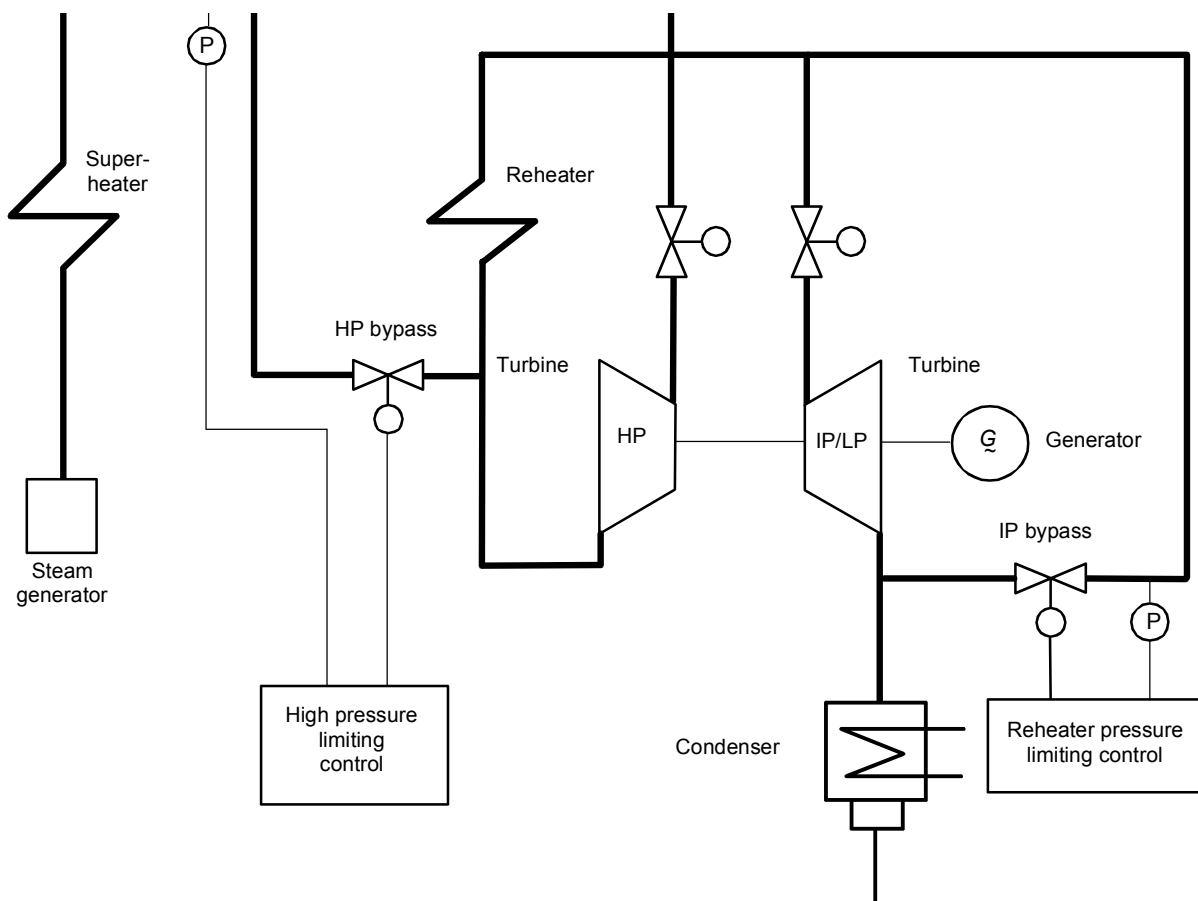


Figure A.1 – Plant circuit diagram for upper steam pressure limiting control using bypass devices

A.2 Description of the control structure

A.2.1 Controlled variable

The controlled variable for the high-pressure bypass device is the high steam pressure.

A.2.2 Reference variable

For limiting control, a control band is set around the operating characteristic, within which the controlled variable may vary within the context of normal operation. The diagram of pressure characteristics for modified floating pressure operation is shown in Figure A.2. Limiting control prevents the controlled variable from falling outside this control band. Only the upper limit of steam pressure is described in this example. The reference variable for the upper limit of steam pressure is formed by addition of a constant Δp to the value of operating characteristic. The value of Δp depends on the control behaviour of the steam generator (construction, firing, design characteristics). It is important here that there be sufficient distance between this new set point and the operating characteristic on the one hand and the value of the highest permissible operating overpressure on the other hand.

The elementary diagram of control of a steam bypass device for conventional power stations is shown in Figure A.3. The operating characteristic for normal operation is formed via a minimum select between the actual pressure value p_{act} and a function p_{target} of the steam mass flow. It runs from a lower limit value p_{min} to an upper value $p_{maximum}$. The rate of change p_{perm} is adjusted using the set point control device. During start-up, the reference variable is formed using other influencing variables which become operative via the switch setting "start-up". The bypass device, however, is not used as a limiting control actuator here.

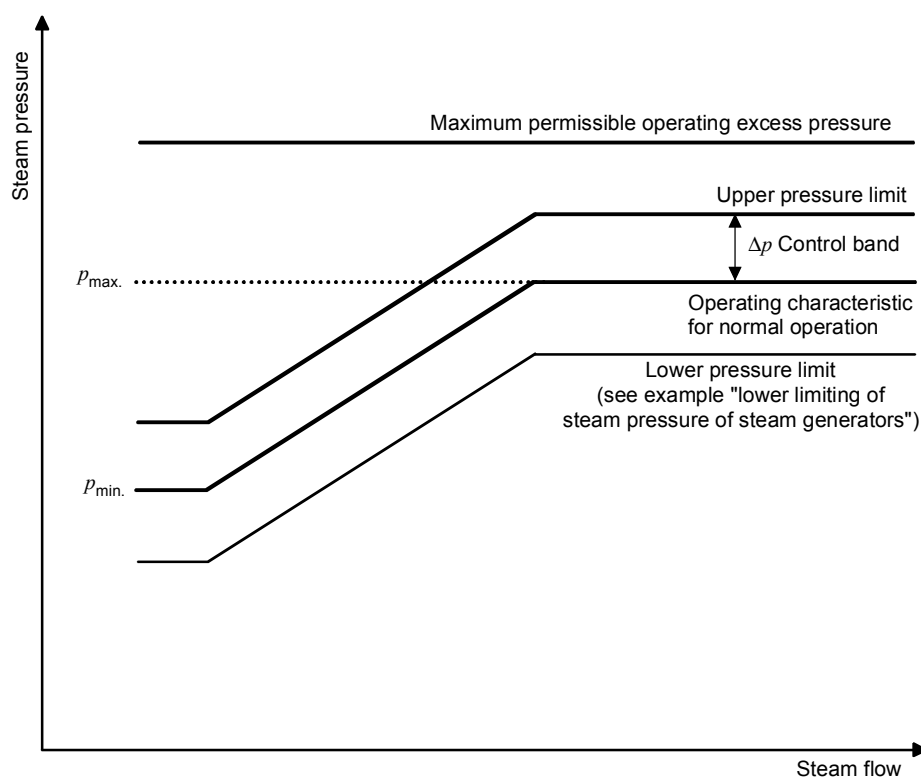


Figure A.2 – Pressure characteristics of a conventional power station unit, shown for modified sliding pressure