PROJECT: MSS54

MODULE: OPERATING MODE MANAGER

AUTHORIZATION

AUTHOR (ZS-M-57)__________________________ DATE _

APPROVED (ZS-M-57) ____________________ DATE ___________

APPROVED (EA-E-2) _____________________ DATE ___________

Changes:

version	Date	comment
S310	2.8.2004	First Version
S320	8.11.2004	Minilift mode added
S330	1.12.2004	Calculation of wi moved to the moment manager
S330	1.12.2004	Renaming of evt_state to bm_evt_state
S330	4.12.2004	Minihub changed from 4V to 3V
S340	8.12.2004	Manual mode no longer a separate operating mode (bm_evt_state)
S360	20.2.2005	Image of hysteresis of KF_BM_AUSWAHL changed, was misleading
S360	30.5.2005	Operating mode transitions now implemented
S370	1.7.2005	4-stroke braking mode added
S380	18.10.2005	12-stroke operating mode newly added
S380	18.10.2005	Operating mode transitions revised in documentation
S380	2.11.2005	When changing from braking operation AÖ=140KW previously AÖ=180KW
S380	2.11.2005	Transition from ZAS changed: AÖ now realized via KL

Table of contents

1 FUNCTIONAL DESCRIPTION

In order to enable optimal throttle-free operation of the EVT engine across the entire operating range, various operating modes of the valve train must be set. To do this, a suitable operating mode is selected in this function depending on the load and speed. The operating modes currently used are briefly described below:

1.1 DESCRIPTION OF THE OPERATING MODES

The following terms are used for the following description:

Designation	Description
UTH	Bottom dead center before the high-pressure phase (combustion)
AO	Outlet Opens
AS	Outlet Closes
EO	Entrance Opens
IT	Entrance Closes
Cycle, work game	The term cycle or working cycle refers to the entire engine process that begins with the charge exchange when the exhaust valve is open. The first valve activities are therefore EO and AS. The charge exchange is then completed by ES. Compression and combustion with expansion now take place. AO is the last action of a working cycle.
Cycle consistency	Cycle consistency describes that all valve timing EO, AS, ES and AO, as well as ignition and injection for each working cycle are kept together for each cylinder. Cycle consistency only has an effect on dynamic processes. Cycle consistency is an important requirement for an EVT engine control unit, since due to the digital control of the valves, each valve timing can be changed significantly from working cycle to working cycle and it must be ensured that all parameters of a working cycle match each other.
pmi	Indicated mean pressure [bar]. Calculation: Integral p dV over one working cycle divided by cylinder volume
wi	Indicated specific work [kJ/dm3]. Calculation: Integral p dV over one working cycle divided by cylinder volume (corresponds to the value of pmi * 0.1)

1.1.1 CLOSING TIME OF THE INTAKE VALVES

These load control methods differ in the position of the closing point of the intake valve. Both FES and SES can be combined with all other methods, e.g. cylinder deactivation, mini-stroke or the 12-stroke method.

1.1.1.1 FES (Early Entry Closes)

In FES mode, the intake valve is closed before the bottom dead center to set a desired torque. After the intake valve closes, expansion occurs up to the bottom dead center.
Since the subsequent compression in the pV diagram lies almost on this expansion line, no losses occur.

1.1.1.2 Late Entry Closes (SES)

Although the SES operating mode has disadvantages compared to FES in terms of consumption and dynamics, it is used at higher engine speeds (above 4000 rpm) because at high speeds the actuating speed of the actuators is not sufficient to implement the FES operating mode. In the SES operating mode, the intake valve is closed after the UTH to set a desired torque. At low torques, the time of closing the intake valves would be so late that the intake manifold would heat up to an unacceptable level and the time of closing the intake valves would come close to the ignition point. The load range for SES is therefore limited to a load of pmi = approx. 5 bar. To set lower engine loads, the SES process must be combined with cylinder deactivation or an i-stroke process (e.g. 12-stroke process). This combination increases the load per fired cylinder again.

1.1.2 NUMBER OF ACTUATED VALVES

These operating modes differ in the number of valves actuated per working cycle. They can be combined with all other processes, e.g. cylinder deactivation or the i-stroke process.

1.1.2.1 4 valve operation (4V)

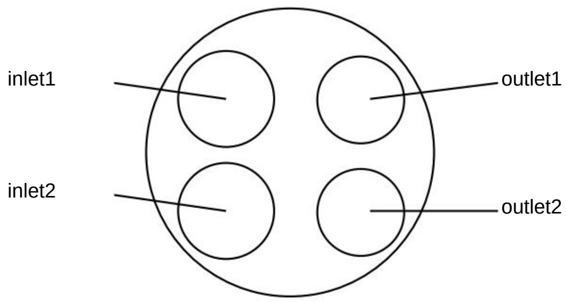
In 4V operation, 2 intake valves and 2 exhaust valves are operated per working cycle.

1.1.2.2 3 Valve operation (3V)

In 3V operation, 2 intake valves and 1 exhaust valve are operated per working cycle. In order to achieve an even load on both exhaust valves, the other exhaust valve is operated alternately per working cycle.

1.1.2.3 2 valve operation (2-V)

In 2V operation, 1 intake valve and 1 exhaust valve are activated per cycle. Since only one injection nozzle is used per cylinder, which injects the fuel into both intake ports, both intake valves are activated alternately from cycle to cycle. In each cycle, the diagonally arranged exhaust valve is activated. This means that, for example, intake 1 and exhaust 2 are activated in one cycle and intake 2 and exhaust 1 in the following cycle (see image). The symmetrical arrangement of the ports thus achieves a reproducible charge exchange.



1.1.3 CYLINDER DEACTIVATION

During cylinder deactivation, cylinders 2 and 3 are deactivated, i.e. only cylinders 1 and 4 are fired. The valves of the deactivated cylinders are kept in the closed state.

1.1.4 12-STROKE OPERATION

The 12-stroke process corresponds to a 4-stroke process in which 8 idle strokes are inserted. One stroke corresponds to 180 degrees of crank angle in a 4-cylinder, i.e. a complete upward movement or a complete downward movement of the piston. Thus, one working cycle of a 12-
Cycle process is 6 crankshaft revolutions.

In the 12-stroke operating mode (bm_evt_state = 7), all cylinders are fired once in the time it takes the first cylinder to complete 3 working cycles. This changes the distance between the high-pressure processes (see Table 1).

		4-stroke	12 – bar
N44 / 4 – cylinder	ZA	180 °KW	540 °KW
N64 / 8 - cylinder	ZA	90 °KW	270 °KW

Table 1: Distance between HD processes N44 / N64

By increasing the number of cycles, the operating point shift and the operating range are further expanded with the SES load control procedure. This can be described as an increased form of cylinder deactivation. The 12-stroke procedure takes place in 4V operation.

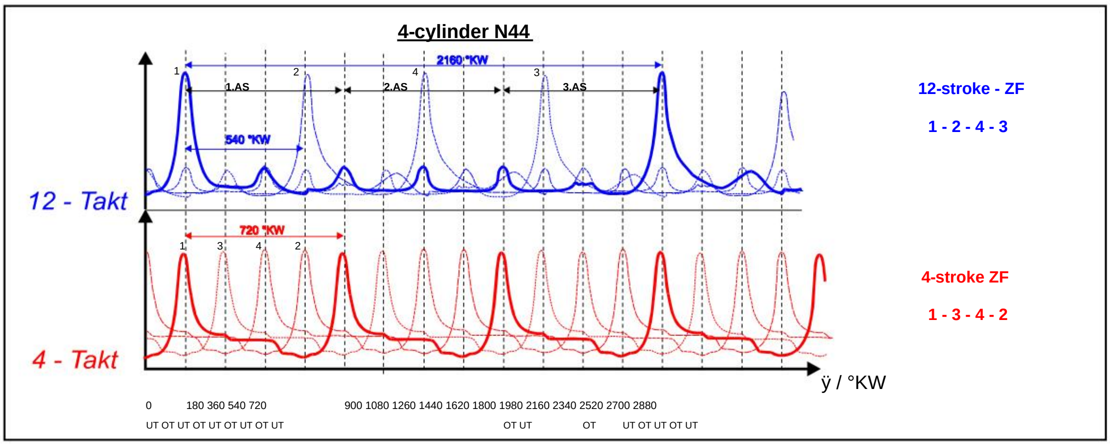


Figure 1.1: Pressure curves in the 12-stroke process (4-cylinder, comparison to 4-stroke Operation)

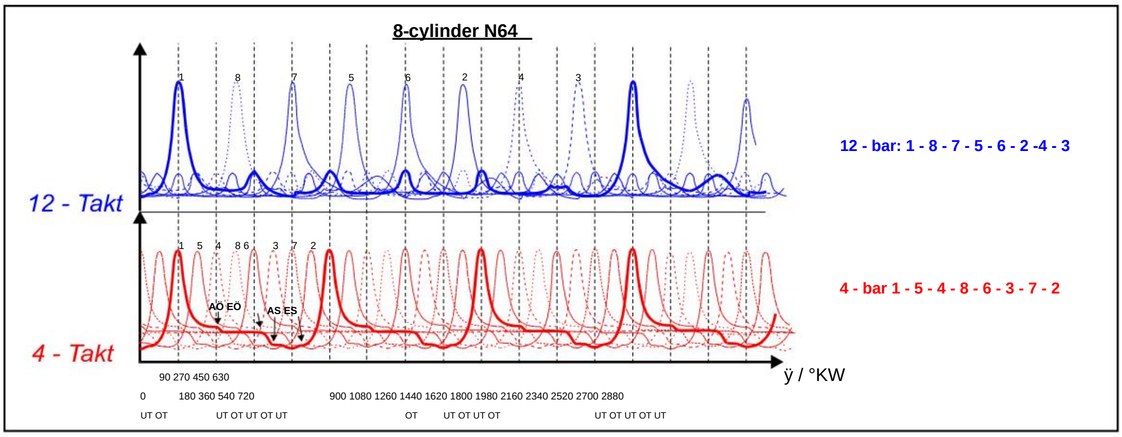


Figure 1.2: Pressure curves in the 12-stroke process (8-cylinder, comparison to 4-stroke Operation)

Advantages of 12-stroke operation:

- Wall film effects in transient operation are avoided due to the same ignition intervals for all cylinders reduced
- Cooling of the cylinders is avoided by alternating "switching off" of the cylinders
- Consumption reduction through shifting the operating point
- Reduction of valve train performance
- Idle cycles can be performed with almost no charge exchange losses

In the 12-stroke process, the control edges for EÖ and ES are controlled in the 3rd ASP, the control edges for AÖ and AS in the 1st ASP of the respective cylinder. This results in a high-pressure process in every 3rd ASP.

beat	1	2	3 4 5 6 7 8 9	10	11	12
Occurrence cylinder	Expansion Pushing Out				suction	compress ssion
Occurrence valves	AÖ	AS	valves closed	EÖ	IT	
ÿ		~~A-spraying~~		A-spraying		

Table 2: Sequence of cycles in 12-cycle operation (no time representation)

1.1.5 MINI LIFT FOR INLET

In contrast to the normal full-lift process, the valves are kept at a small valve lift (mini-lift) in the mini-lift process. This is made possible by a controlled actuator operation in which an actuator lift sensor is used. The mini-lift reduces the intake manifold pressure waves because the valves are not closed so suddenly. The valve seating speed can be minimized more easily because only small lifts and speeds are used.

In addition, for low speeds and engine loads, an option is offered to generate turbulence and mixture preparation, which can improve engine efficiency. The mini-stroke can also be changed as a parameter. This means that the size of the mini-stroke is available as an additional parameter for setting an engine load. In mini-stroke mode, only the inlet is operated with a small amplitude, the outlet with full lift. Two inlet valves and only one outlet valve (3V) are operated in a toggled manner.

1.1.6 BRAKING OPERATION 4-STROKE

Special valve timing allows the engine to be used for braking, whereby the braking torque can be continuously adjusted via the valve timing. Only the exhaust valves are used to avoid flushing the fresh mixture. The exhaust valves are closed in the area of bottom dead center. Compression then takes place until a desired pressure is reached, at which point the exhaust valve is opened. The compressed gas now flows from the cylinder into the exhaust system. As the piston moves downwards, gas is again sucked from the exhaust system into the cylinder. To achieve maximum braking effect, the process described should be repeated with each crankshaft revolution. This corresponds to a 2-stroke process.

Braking should only be possible at a speed of twice the idle speed (currently n=1400 min-1). During braking, a high negative **pmi** is intentionally generated in order to decelerate the vehicle without the mechanical brakes.

During braking, no fuel is injected and the gas exchange losses are only realized via the exhaust valves. The negative torque is achieved by the exhaust valve closing around bottom dead center and opening at a certain cylinder pressure, thus generating compression losses. The inlets remain closed.

Machine Translated by Google

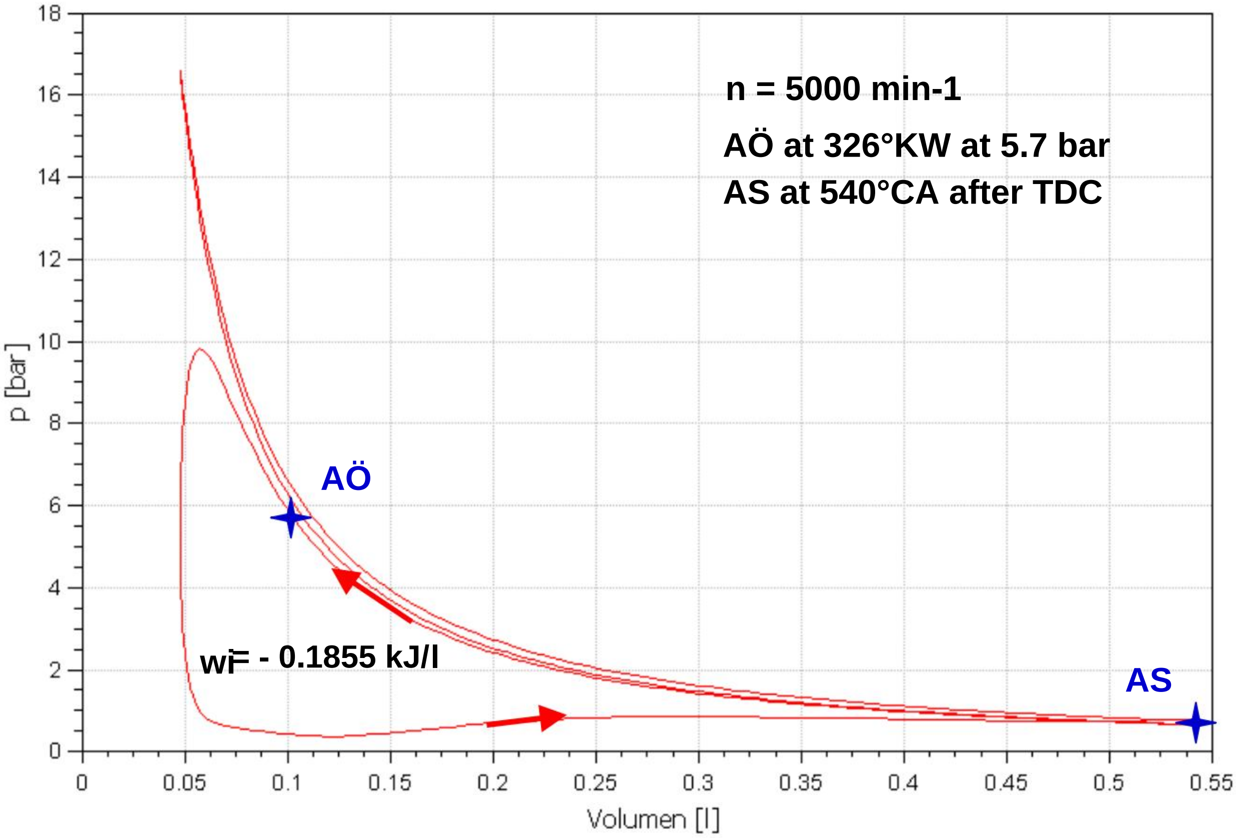


Figure 2 4-stroke brakes

In four-stroke braking, the exhaust valve is closed around bottom dead center (540°CA after ZOT). The position of exhaust valve therefore determines the respective filling. Depending on the desired braking torque, exhaust valve is between BDC and TDC (180°...360°CA after ZOT). The later the opening time, the higher the compression losses and thus the braking performance that can be achieved.

The maximum possible braking torque is limited by the cylinder pressure at the time of AÖ. If the cylinder pressure at AÖ is too high, the valve cannot open against the gas force and will only open at an indeterminate time after TDC, which means that the braking power cannot be clearly defined.
This would also reduce the braking torque because the valve opens during the decompression phase.

Braking is only carried out via the outlet valves to avoid air being pushed through. In addition to the acoustics, the high pressure amplitudes would also be problematic if braking were carried out on the suction side.

1.2 TRANSITIONS OF OPERATING MODES

In contrast to the transition functions in conventional engines, these transitions only consider the transition from one working cycle to the next, and do so individually for each cylinder. Initially, only the valve train-specific transitions are to be implemented. The transitions for the fuel path will be implemented at a later point in time. In the following description, the first working cycle is referred to as working cycle_1 and the following one of a cylinder is referred to as working cycle_2.

1.2.1 DIFFERENT NUMBER OF ACTIVE EXHAUST VALVES

Since the opening of the exhaust valves (AO) is always the last action of a working cycle, when changing from 4V operation to 3V or 2V operation, the number of exhaust valves opened does not match the number of valves to be closed. In this case, AO belongs to working cycle_1 and AS to working cycle_2, i.e. 2 exhaust valves are opened, but only one exhaust valve is closed. In this case, special treatment must be carried out that closes the 2nd exhaust valve at the same time as the first exhaust valve. In the reverse transition from 3V or 2V operation to 4V operation, only one exhaust valve is opened, but both exhaust valves are to be closed. In this case, the closing of the 2nd exhaust valve must be suppressed.

1.2.2 TRANSITION TO CYLINDER DEACTIVATION

The transition from a working cycle in which a cylinder is operated to a working cycle in which the cylinder is switched off should take place as follows:

1. normal outlet opening as the last action of the fired working cycle
2. Exhaust closing in gas exchange TDC

Now all valves are closed and as long as cylinder deactivation is active, no valves should be operated.

1.2.3 TRANSITION FROM CYLINDER DEACTIVATION

In the PV diagram of a deactivated cylinder, the compression and expansion lines are almost identical. A strong negative pressure is reached at bottom dead center.
If the exhaust valve were opened at this time, the exhaust gas would be released from the exhaust system. flow into the cylinder at the speed of sound and stir up oil. This oil would enter the exhaust system unburned during the subsequent compression. To avoid this problem, the exhaust valve should be opened as late as possible.

The transition from a working cycle in which a cylinder is switched off to a fired
The work cycle should be as follows:

1. Outlet opening is replaced by the value from the characteristic curve **KL_BART_AO_ZAS .**
2. Now all valve control parameters of the fired working cycle can be used. (Don't forget that all opened exhaust valves must be closed!)

1.2.4 TRANSITION FROM FIRED TO BRAKING MODE (4-STROKE)

During the transition from fired operation to braking operation, the AÖ control edge from fired operation is still used at the first ASP and the AS control edge from braking is already used.
The inlet control edges are suppressed.

Example (fired operation -> braking):

transition

fired	transition	brakes	brakes
AÖ FES = 180	AÖ FES = 180	AÖ BB = 320	AÖ BB = 320
AS FES = 360	AS BB = 540	AS BB = 540	
EÖ FES = 360	EÖ BB = --	EÖ BB = --	
ES FES =440	ES BB = --	ES BB = --	

fired → **brakes** →

1.2.5 TRANSITION FROM BRAKING TO FIRE (4-STROKE)

When changing from braking to fired operation, the already calculated control edge for AÖ must be overwritten (by the value AÖ=140°KW after ZOT).

Example (braking -> fired operation):

transition

brakes	transition	fired	fired
AÖ BB = 320	AÖ BB = ~~320~~ 140	AÖ FES = 180	AÖ FES = 180
AS BB = 540	AS FES = 360	AS FES = 360	
EÖ BB = --	EÖ FES = 360	EÖ FES = 360	
ES BB = --	ES FES =440	ES FES =440	

brakes → **fired** →

1.2.6 TRANSITION FROM ZAS TO 12-BAR

When switching from operation with ZAS, the control edges for AÖ and AS are controlled in the first ASP, the control edges EÖ and ES are not controlled.
The control edges AÖ and AS are only activated again 3 ASP later, the control edges for EÖ and ES are activated again after 8 idle cycles.

The injection for all cylinders must be activated and must be controlled with 8 idle strokes as shown in Table 2.

It must be ensured that the transition between the two operating modes is only possible at the time when there is an overlap in the high-pressure process of the active cylinders of both operating modes. (ÿ see Table 3 and Figure 1.4.: A change from ZAS to 12-stroke is only possible in the areas marked in red.)

	ZAS ÿ 12 T	12 T ÿ ZAS	4 T ÿ 12 T	12 T ÿ 4 T
N44	1080	5401	1802	540
N64	540	2701	902	270

Table 3: KW difference for possible BA change

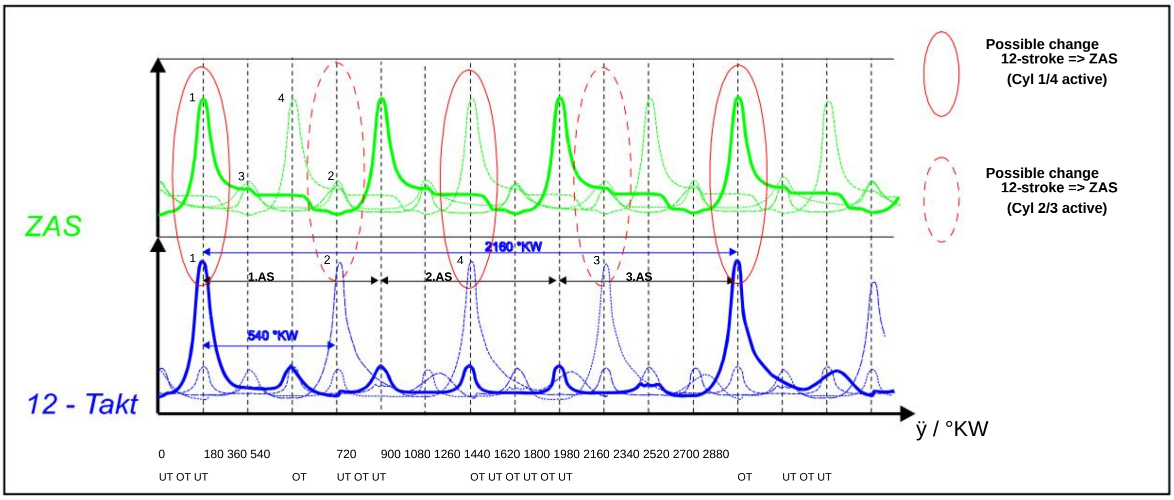


Figure 3: **Possible transitions from ZAS to 12-stroke (with ZAS cylinders 1 and 4 active)**

1 Change to the next possible cylinder group
2 changes gradually

1.2.7 TRANSITION FROM 12-BAR TO ZAS

When changing from 12-stroke operation to ZAS operation, the control edges for the intake valves must be controlled again in the 1st ASP.
The cylinders are controlled according to the ignition sequence 1-3-4-2 (4-cyl), cylinders 2 and 3 (or 1 and 4) are not controlled (=> ZAS operation).
A change from 12-stroke to ZAS is possible every 540 °CA [270 °CA]. Depending on which cylinder has an overlap in the HP process at the time of the change, a decision is made as to which group changes to ZAS operation.

The transition from 12-stroke to ZAS does not have to take place at times when there is an overlap in the HD process.

1.2.8 TRANSITION FROM 4-STROKE TO 12-STROKE

The change from 4-stroke to 12-stroke operation can occur every 180 °CA [90°CA] (ÿ Table 3).
The change is carried out "step by step", meaning that each cylinder that has completed the HD process in 4-stroke mode switches to 12-stroke mode and is then operated with a new ignition sequence and ignition interval.

1.2.9 TRANSITION FROM 12-BAR TO 4-BAR

The change from 12-stroke to the other operating modes takes place in the same way as the transition from 12-stroke to ZAS. However, all cylinders are controlled according to the "normal" ignition sequence.
The transition from 12-stroke operation to 4-stroke operation can take place every 540 °CA on a 4-cylinder engine, but generally always at the time when there is an overlap of the HP processes. (ÿ see Figure 4 A change from 12-stroke to 4-stroke is only possible in the areas marked in magenta.)

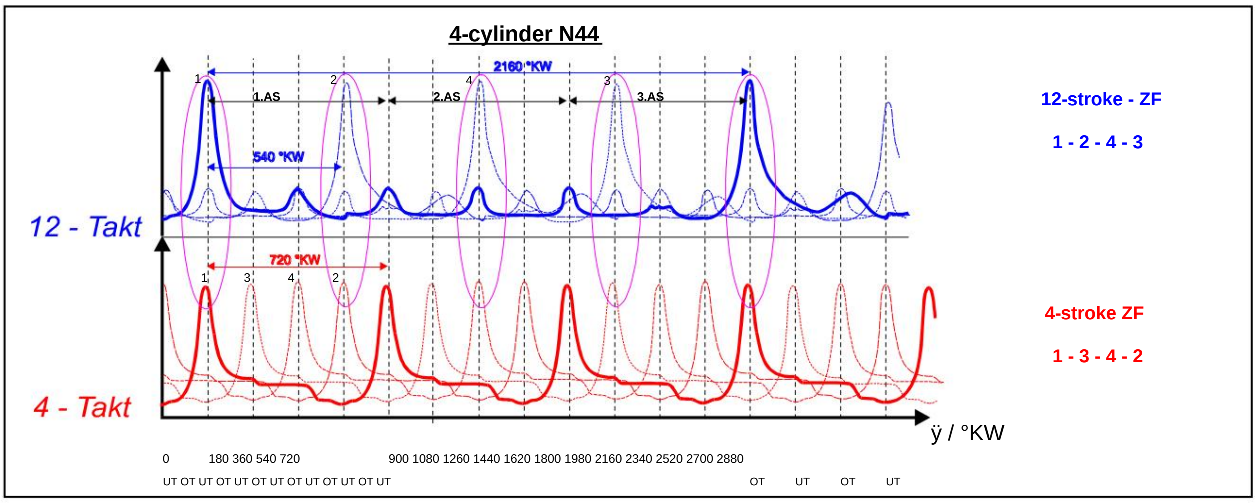


Figure 4: **Possible transitions 12-stroke ÿ 4-stroke**

1.3 CALCULATION OF THE OPERATING MODE

The main part of the function is made up of the look-up tables **KF_BM_AUSWAHL** and **KF_BM_AUSWAHL_KATH** for cat heating (only in the next SW version!!!). These look-up tables calculate the operating mode **bm_evt_state** via the inputs **wi** and **n ,** without interpolating the z values .

Table 4 shows the definition of **bm_evt_state:**

bm_evt_state 0 1	**operating mode**
	cylinder deactivation + SES + 4 valves
	cylinder deactivation + FES + 3 valves
2	FES / 2V
3	FES / 3V
4	FES / 4V
5	SES / 4V
6	4-stroke brakes
	12 stroke / 4V
7	Cat heaters / 3V
8	cat heaters / mini lift
9	catalyst heating / cylinder deactivation
10	Minihub / 3V
11	full load / 4V
12 13	start

Table 4 Operating modes

To prevent jumping back and forth between the states in a load condition, the inputs are switched via a hysteresis.

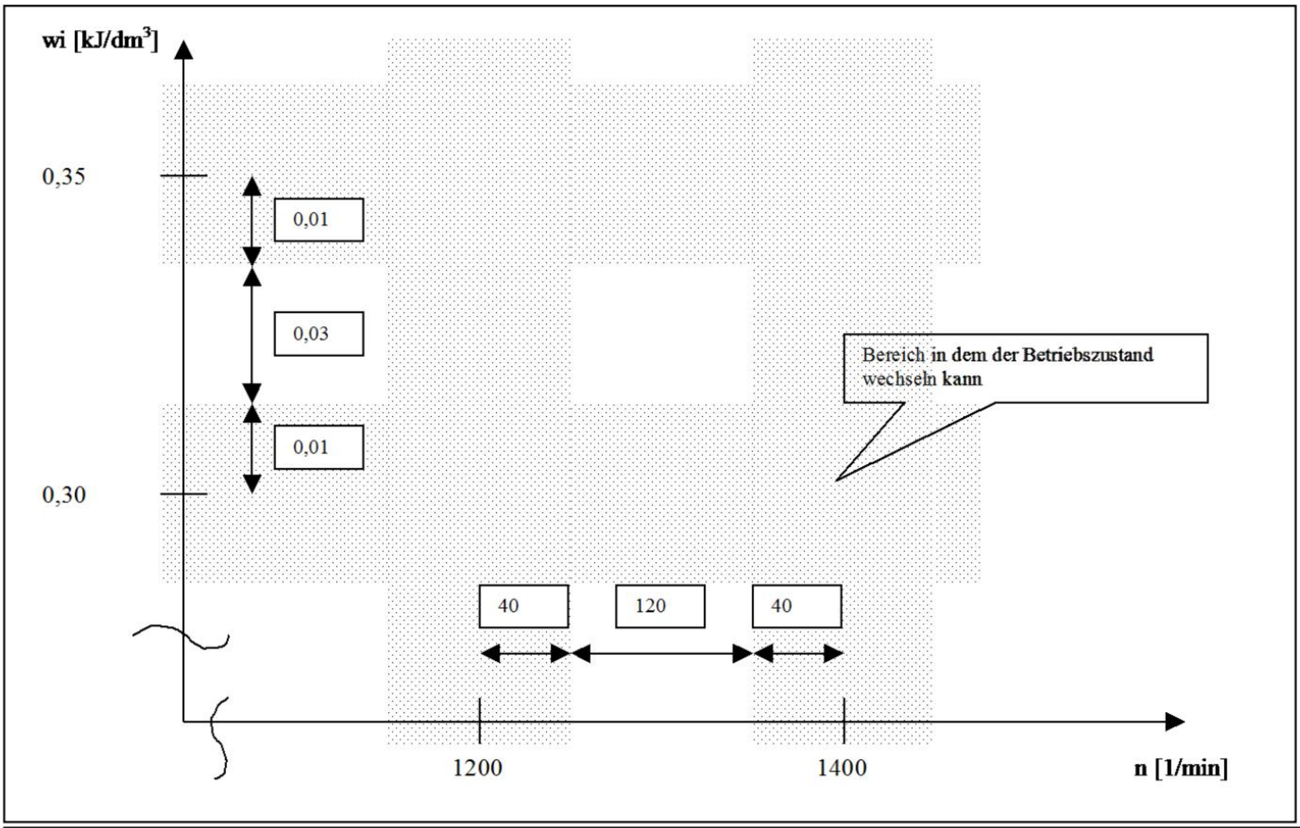
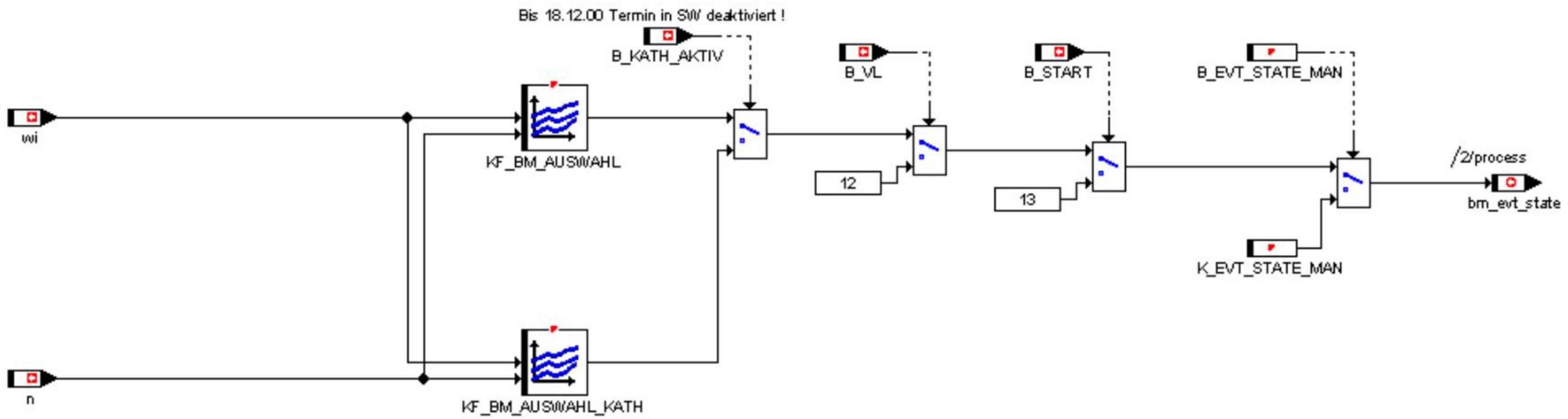


Figure 5 Hysteresis of the axes of KF_BM_AUSWAHL

The state can only change when the input variable enters the hatched areas. The gaps remain undefined and **bm_evt_state** retains the last value. The distance between the support points of the speed axis must not be less than 200 rpm. The same applies to the wi axis; here too, the distance must not be less than 0.05!

When defining the support points for the various operating modes in **KF_BM_AUSWAHL** and **KF_BM_AUSWAHL_KATH,** it is important that they correspond to the limit support points of the associated basic data set - control edges, ignition angle, air mass, throttle angle and advance angle (see evt_momentenrealisierung.doc)!

1.4 FUNCTIONAL CIRCUIT DIAGRAM



2 DATA OF THE OPERATING MODE MANAGER

The function is calculated in the angle-synchronous task in the master.

Description of the variables:

bm_evt_state	operating state evt	ub

Description of the application data:

KF_BM_SELECT	map operating state evt	uw/uw/ub
KF_BM_AUSWAHL_KATH	Map operating state possibly with catalytic converter	uw/uw/ub
B_EVT_STATE_MAN	Switching to manual specification of bm_evt_state manual	ub
K_EVT_STATE_MAN	bm_evt_state specification	ub
KL_BART_AO_ZAS	Control edge AO at transition from ZAS	uw/uw