OPEN DRIVE

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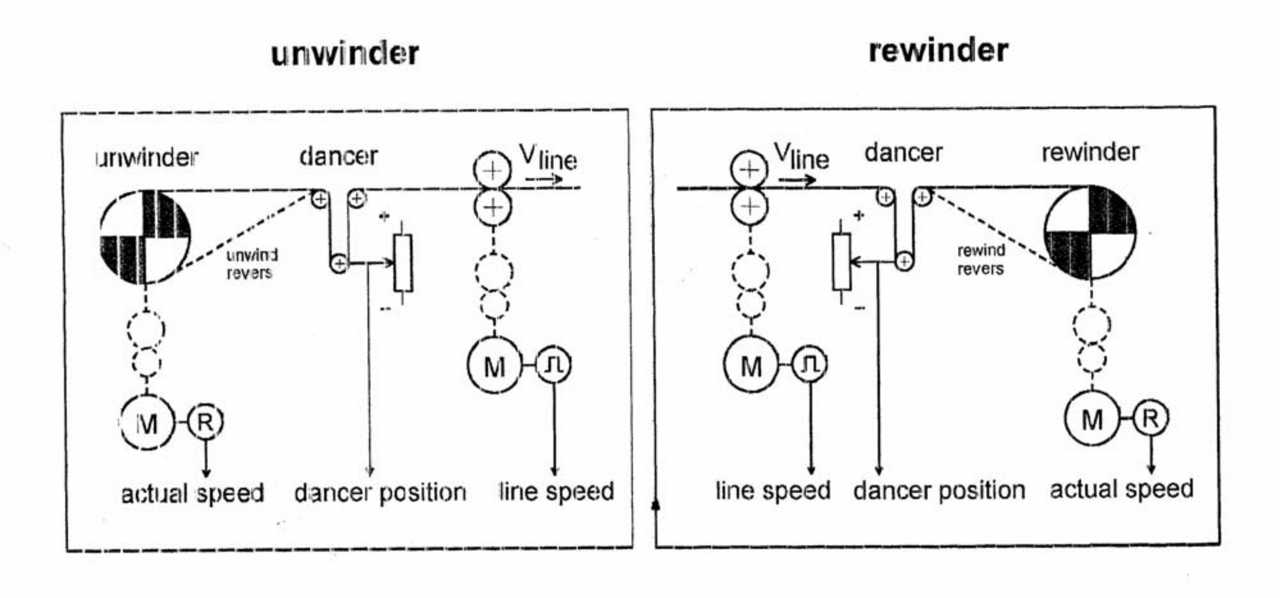
Application n°001
Winding/Unwinding
with dancer
and diameter calculation

INDEX

The following application of the OPEN DRIVE is able to unwind or rewind a wire, keeping a constant tensile force on the material, by using a dancer.
The drive follows the line speed taken by a pulley on which runs a wire (with no sliding between them); the signal can be taken by an encoder positioned on the pulley shaft or by a tachometric dynamo.
The unwinder/rewinder is completed with the calculation of the servo diameter in order to follow in a really fast way the line signal. The servo diameter will keep the dancer in its "0" position through all the coil duration (from the min to the max diameter), also with not moving line.



1. CONFIGURATION OF THE APPLICATION

1.1. Application's parameters

PAR	DESCRIPTION	Variation RANGE	Default VALUE	Normalization UNIT	Internal represent
P180	Max. dancer's correction admitted	0.0÷100.0	10.0	% n_{MAX}	16383
P181	Min. line speed for the diameter calculation	0.0÷100.0	5.0	% n_{MAX}	16383
P182	Position's reference of the dancer	± 100.0	0.0	% stroke	16383
P183	Min. number of pulses to calculate the diameter	0 ÷ 19999	19000		1
P184	Initial diameter (dstart)	0.0÷200.0	70.0	% dmin/dstart	16383
P185	Filter on the correction term from the diameter calcula-tion	0.0 ÷ 1999.9	936.0	ms	10
P186	Kp PID dancer, proportional gain	0.5÷100.0	1.0		10
P187	Ta PID dancer , lead time constant	0.1÷1500.0	100.0	ms	10
P188	Kd PID dancer, gain of the derivative part	0.00 ÷100.0	0.00		100
P189	Tf PID dancer, filter on the input	0.0 ÷ 25.0	1.0	ms	10
P190	Max speed unwinder/rewinder (n_{MAX})	100 ÷ 30000	2037	rpm	1
P191	Maximum measurement frequence for channel	0.01 ÷ 199.99	18.11	KHz	100
P192	Voltage related to the maximum line speed	2500 ÷ 10000	10000	mV	1
P193	Maximum variation of the expected diameter (d_{MAX}/dmin)	1.0 ÷ 100.0	6.0	dmin	10
P194	Maximum variation total inertia unw/rew (J_{MAX}/Jmin)	1.0 ÷ 100.0	1.0	Jmin	10
P195	Dead band dancer control	0.0 ÷ 100.0	0.0	%stroke	16383

1.2. Application's connections

CON	DESCRIPTION	Variation RANGE	Default VALUE	Default meaning	Internal repr.
C90	Rewinder/unwinder mode (reverse output PID)	0,1	0	No reverse	1
C91	Encoder on the line (0) or tachometric dynamo (1)	0,1	0	Encoder	1
C92	Reverse measure of speed line	0,1	0	No reverse	1

1.3. Application logic inputs

INPUT	LOGIC FUNCTION ASSIGNED
I29	Preset initial diameter value (P184) on high active level (*"Preset speed ratio"*)
I30	Reverse revolution verse ("*Un/rew. revers*")
I31	Reset the output of PID dancer ("*Reset overlay*")

1.4. Application analog inputs (unchangeable)

INPUT	LOGIC FUNCTION ASSIGNED
A.I.2	Dancer position
A.I.3	Tachometric dynamo

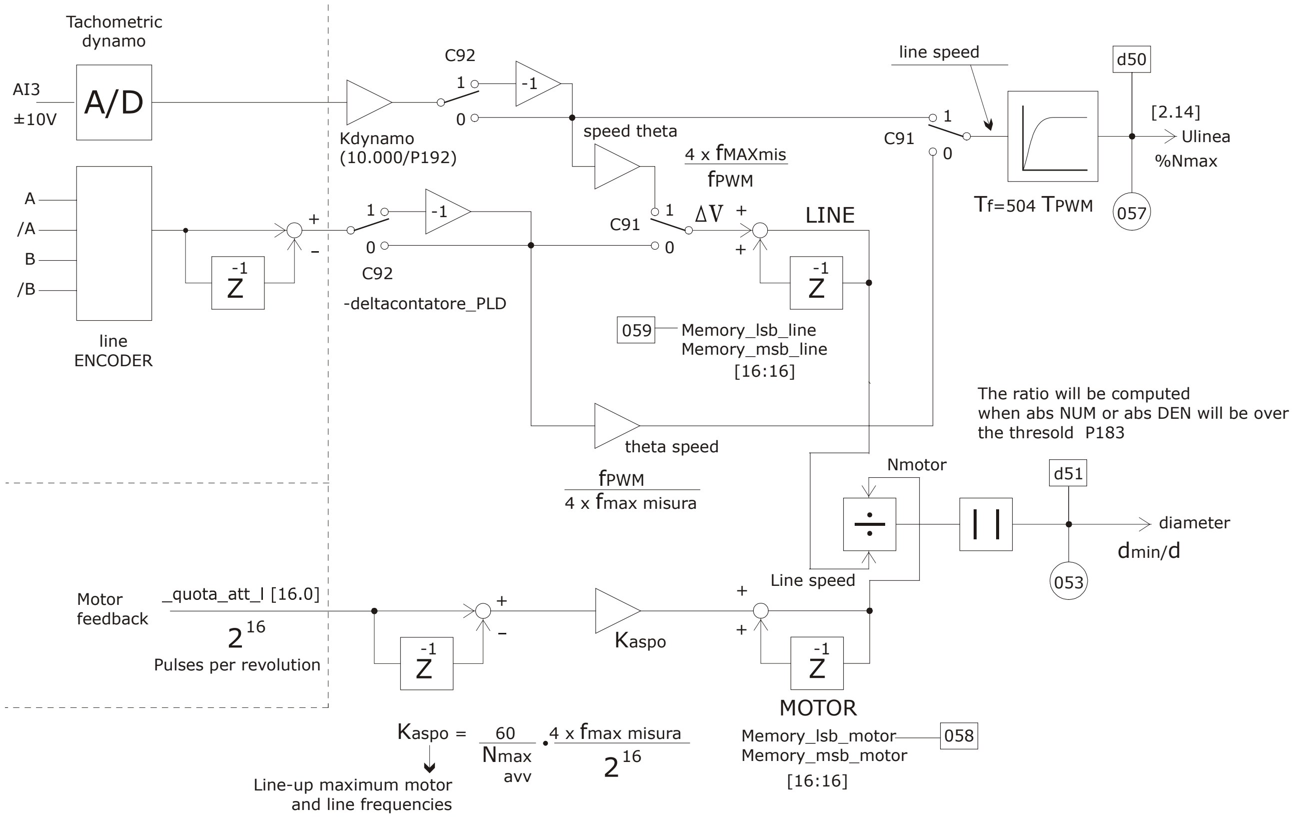
1.5. Analog outputs and monitor application

OUTPUT	INTERNAL VARIABLE ASSIGNED	Normaliz. Unit	Intern. Representation
O53	Computed diameter	% dmin/d	16383
O54	Applicated diameter	% dmin/d	16383
O55	Output PID dancer	% n_{MAX}	16383
O56	Maximum limit output PID dancer	% n_{MAX}	16383
O57	Line speed filtered (504xTpwm , equal to 100ms to 5KHz of PWM)	% n_{MAX}	16383
O58	Counter of pulses motor speed		1
O59	Counter of pulses line speed		1
O60	Line speed	% n_{MAX}	16383
O61	Memory of the integral part of the PID dancer	% n_{MAX}	16383

1.6. Application internal sizes

INT	INTERNAL VARIABLE ASSIGNED	Normalization unit	Internal representation
d50	Filtered line speed (504xTpwm , equal to 100ms at 5KHz of PWM)	% n_{MAX}	16383
d51	Computed diameter	% dmin/d	16383
d52	Applicated diameter	% dmin/d	16383
d53	Read dancer's position	% stroke	16383
d54	Output PID dancer	% n_{MAX}	16383

2. MEASURE OF THE SPEED LINE AND COMPUTING OF THE DIAMETER



The line speed can be measured by using a tachometric dynamo or by having a digital signal coming from an Encoder; the selection is made setting rightly the connection **C91** : if 0 the control manages a signal from Encoder, if 1 it manages an analog signal (connected to the A.I.3) coming from a tachometric dynamo.
In both cases thanks to the connection **C92=1** the speed sign of measured line can be reversed.
About parameterisation it is necessary to correctly set the parameters from **P190** to **P192**, due to the fact that the work will be based on the percent of this values.
The data that has to be written in **P190** it is the maximum speed of the motor of the unwinder/rewinder in rpm.
Note : the maximum line speed in m/min (Vel_linea $_{MAX}$), the minimum diameter of the winder in m (dmin) and the reduction ration (R), the revolution speed of the motor in rpm (n avv $_{MAX}$)
It will be:

$$n_{\text{avv MAX [rpm]}} = \frac{\text{Vel\_linea}_{\text{MAX [m/min]}} \cdot R}{\pi \cdot d\,\min[m]}$$

E. g. :

Vel_linea $_{MAX}$ = 400m/min
d min = 0,3m
R = 4,8

} n avv $_{MAX}$ = 2037 rpm $\rightarrow$ P190

The other two parameters depend on the feedback type connected to the line :

2.1. Encoder (C91=0)

In this case it is necessary to set the parameter **P191** in KHz the frequence for channel related to the maximum line speed.
Note : the maximum line speed in m/min (Vel_linea $_{MAX}$), the diameter of the pulley measured in m (dpul) and the number pulses per revolution of the Encoder N_{ENC} , the maximum measure frequence for channel, will be :

$$f_{mis\ MAX\ [Hz]} = \frac{Vel\_linea_{MAX[m/min]}}{60} \cdot \frac{N_{ENC}}{\pi \cdot d_{pul}[m]}$$

E. g. :

Vel_linea $_{MAX}$ = 400m/min
dpul = 0,12m
N_{ENC} = 1024 ppr

} f mis $_{MAX}$ = 18,11 KHz → P191

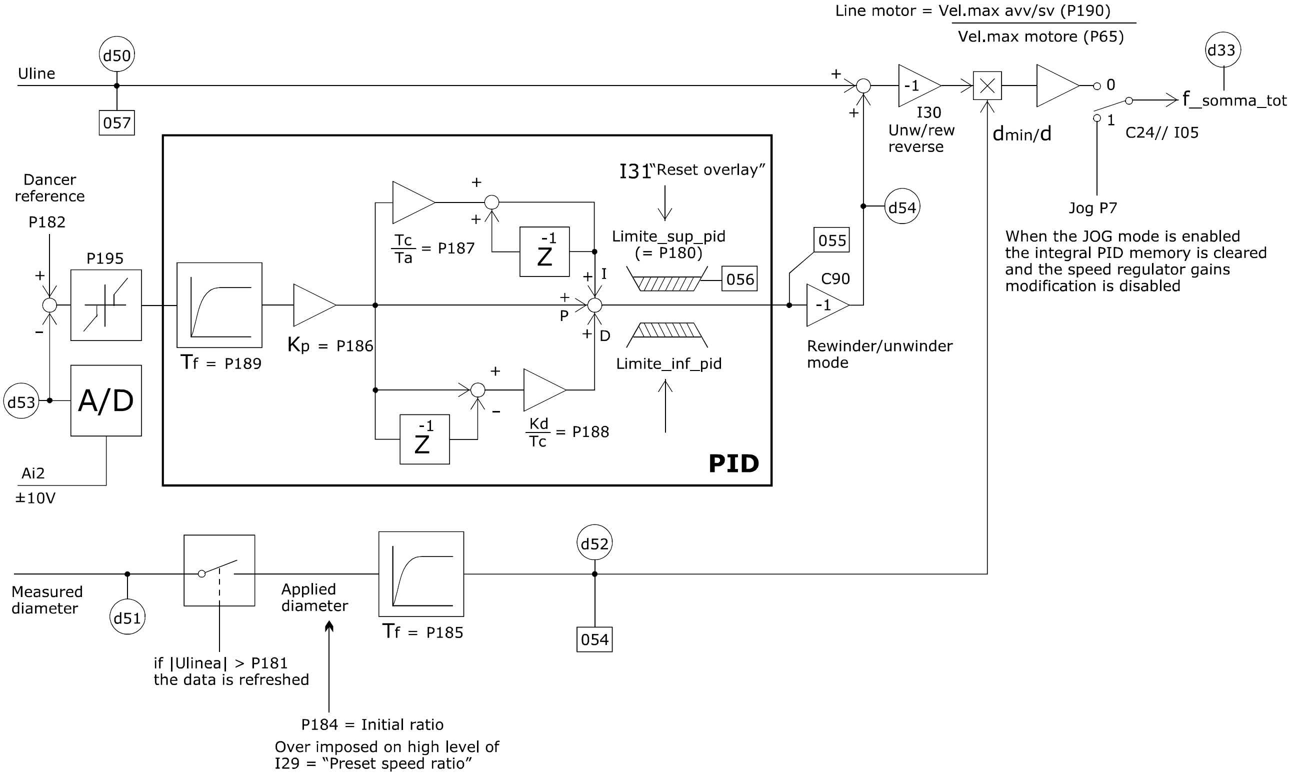
Due to the fact that all the rising edges of the Encoder signal are computed, the maximum frequency managed in the internal part of the converter is 4 times the one reported in P191. The pulses counter will be refreshed with this frequency and the diameter will be computed when the pulses accumulated will be over the threshold reported in P183.

2.2. Tachometric dynamo (C91=1)

In this case it is necessary to set in the parameter **P192** in mV the voltage produced by the tachometric dynamo related to the maximum line speed.

Not having any limit about the internal representation of the line frequency related to the maximum speed, the parameter **P191** has been chosen to set it. So the maximum line speed reported by the tachometric dynamo will correspond *internal* line frequency equal to 4 x P191 KHz. (this obviously values only for the diameter computation, that will be done every time the pulses accumulated will be over the threshold reported in P183).

3. ADJUSTMENT OF THE DANCER AND CORRECTION OF THE SERVO DIAMETER



3.1 Adjustment of the dancer

The PID of the dancer manages the error between the dancer's reference set in **P182** and the real position measure (visualizable in d53)

It has been implemented a dead band on the position's error settable in amplitude in **P195** in percent of the stroke. This dead band's function is to keep perfectly standstill in position the dancer also when the line is at zero speed. The dead area is active only if the line speed is less than 5% of its maximum value.

On the input of the PID there is a 1st order filter with time constant settable in ms in **P189**.
The gain of the proportional part it is set in **P186**, the lead time constant is in ms in **P187** and the gain of the derivative part in **P188**. The maximum and minimum correction limit of the PID is set by the parameter **P180** only if the logic input **I31** ("Reset overlay") that resets the limit is not active.
The PID is provided with a circuit against wind-up to avoid accumulating error in the memory of the integral part when the output is saturated.

With the connection **C90** it is possible to reverse the PID output to adapt the control to the unwinder or rewinder function.

3.3 Diameter calculation

The diameter's calculation is made by the ratio between the rotation's speed of the motor and the line's speed.
Both speeds re managed in frequency and there is an internal coefficient (Kaspo) used to align the two frequencies when the line speed is at maximum value with minimum roll diameter: in that case the motor runs to its maximum speed (P190). So in this way it will be possible to measure the roll diameter respect to its minimum value.
In order to improve the precision the work will be done in space and it is possible to set in parameter **P183** the minimum pulses' number to refresh the calculation.
P183's choice is made as a trade-off between:

refresh's time of the measurem (P183 low) ←→ measurement resolution (P183 high)

For having a good resolution the threshold has to be greater than 1000 pulses but the diameter upgrade cannot be to slow especially for thick rolled materials: the right choise depends on the application.
The following considerations are important if the diameter changes quickly, on the contrary it is possible to leave P183=19000 (default) that means to work with the maximum resolution.

On diameter calculation, the line pulses are the first to reach the P183 threshold because the line and motor frequency are equal only with minimum diameter, in the other case the line frequency is the greatest.

Material pulses per meter **Im** = $\frac{\text{fline} \times 4}{\text{v line max}/60}$ with f line = line frequency measured in Hz

v line max = max line speed in m/min

Material lenght to refresh the diameter **Lm** = $\frac{\text{Threshold}}{\text{Pulses per meter}} = \frac{\text{P183}}{\text{Im}}$ meter

The worst case is with minimum roll diameter, because with high motor speed there will be more turns and therefore the diameter changes more quickly:

Maximum roll revolutions **n giri** $_{\mathbf{MAX}}$ = $\frac{\text{Material lenght to refresh}}{\text{Minimum circumference}} = \frac{\text{Lm}}{\pi \times \text{dmin}} = \frac{\text{P183}}{\text{Im} \times \pi \times \text{dmin}}$

The bond raises from how many rool's revolutions can be tolerated before the diameter calculation is refreshed and this set the upper threshold limit, while the lower limit (1000) is imposed by resolution:

$$1000 \leq \text{P183} \leq \text{Pulses per meter} \times \text{Maximum roll revolutions} \times \text{Minimum circumference} = \text{Im} \times \text{n giri MAX} \times \pi \times \text{dmin}$$

The minimum diameter is a process data, the maximum roll revolutions are imposed like bond on diameter refresh time and the Pulses per meter depends on the line speed measure.
If the condition isn't respected it will be necessary to increase the material pulses per meter or increasing the line Encoder resolution or decreasing the measuring pulley diameter.

The diameter periodically computed) is shown in the internal value **d51**.
Every new data will be used in the servodiamter correction only if the line speed (**d50**) is over a threshold set in the parameter **P181** (in % of the maximum line speed).

It is possible to force the initial value of the diameter by using the logic input **I29** ("Preset speed ratio"): on the high level the value set in the parameter **P184** is set in the actual diameter.

In order to have a slowly correction of the servodiameter , specially if the initial data is different from the real one, there is a filter of the 1st order with time constant settable in ms in **P185.**

3.2 Working mode in Jog of speed

To give a digital reference of speed to the motor it is possible to bypass the unwinder/rewinder control. To obtain this it is necessary to set C24=1or I05=H and act on the standard parameter P07 that is in percent of the maximum speed of the motor set in P65.

4. VARIABLE GAINS WITH THE DIAMETER

In the application unwinder/rewinder the total inertia reported on the motor's axis can heavily change during the working. It has been introduced a compensation term to guarantee the stability and the dynamic response of our converter.

Set in **P193** the ratio between thre maximum and the minmum coil's diameter and in **P194** the corresponding ratio between maximum an minimum load's inertia .

$$\text{coeff\_Kp} = 1 + \left(\frac{J_{MAX}}{J_{min}} - 1\right)\left(\frac{1}{\frac{d_{MAX}}{d_{min}} \cdot \frac{d_{min}}{d}}\right)^4 = 1 + (P194 - 1)\left(\frac{1}{P193 \cdot \frac{d_{min}}{d}}\right)^4$$

When the machine is in its starting phase, the right gains of the speed regulator with the minimum diameter has to be found and then it is necessary to rightly tune P194 to guarantee a perfect dynamic also with the maximum diameter.