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EDITORS:	ALEXANDRE FERREIRA DA SILVA ANÍBAL CARVALHO
VERIFIED BY:	
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PREFACE

This document contains a description of the maintenance function «Perform trend analysis of MSV -Turbine efficiency».

1. OBJECTIVE OF FUNCTION

The function objective is to reveal the turbine efficiency degradation resulting from wear due to cavitation and/or abrasion, allowing the maintenance operator to forecast (schedule) runner repairs, taking into account the previous operating conditions and the expected ones. Runner excessive degradation can ultimately cause damage to the rest of the hydraulic machine.

The function performs trends of efficiency historical data of similar operating conditions, since efficiency values are dependent on operating conditions of power plant.

So, a previous step will be to establish classes of operating heads and guide vanes openings (or power values) and to classify the operating hours accordingly, that is, to set up a statistical distribution of operating hours.

2. FUNCTION ENVIRONMENT

The function is a part of the forecasting maintenance domain.

The sequence of requests and responses necessary to utilise this function is the following:

Event	Request/Response (RQ/RS)	From	To
Perform computation of MSV	RQ	MO	Function
Acknowledge	RS	Function	MO
Acquire (retrieve) calculated data (operating hours distribution) and historical data (operating points quantities)	RQ	Function	Historical Data Base
Compute efficiency weighting factors	RQ	Function	Function
Choose (find) class head for each operating point and convert associated quantities (flow , power and efficiency) to the class mid-point	RQ	Function	Function
Calculate weighted average efficiency	RQ	MO	Function
Present results	RS	Function	MO

3. INPUT DATA DEFINITION

Calculated data:

1 operating hours distribution $h_{i,j}$

turbine mode:

	α_1	...	α_i	...	α_n	total
H_1	$h_{1,1}$					$h_{.1}$
...						
H_j			$h_{i,j}$			
...						
H_m						
total	$h_{1.}$					$h_{..}$

where:

α_i - guide vane opening (class mid-point), %
H_j - head (class mid-point), m

pump mode:

H_1	
...	
H_j	
...	
H	
total	

where:

H_j - head (class mid-point), m

<u>Configured data (historical data)</u>

1 turbine efficiency:

time t_1 *(S6 function tests date):*

guide vane opening (α), %	α_1	...	α_i	...	α
headwater level (z_3), m					
tailrace level (z_4), m					
head ($H = E / \bar{g}$), m					
flow (Q), m^3/s					
power (P), kW					
efficiency (η), %					

time t_k
...

time t_l

2 pump efficiency:

time t_1*:*

headwater level (z_3), m	
tailrace level (z_4), m	
head ($H = E / \bar{g}$), m	
flow (Q), m^3/s	
power (P), kW	
efficiency (η), %	

time t
...

time t_l

4. OUTPUT DATA DEFINITION

Output from function:

1 Historical data

2 Weighting factors (turbine and/or pump mode)

- table $w_{i,j}$
- histogram (3 D)

3 Turbine efficiency values

for each pair H_j, α

- table:

date	t_1	...	t	...	t_l
flow (Q), m^3/s					
power (P), kW					
efficiency (η), %					

- graphic: efficiency plotted against time

for each H_j

- graphic: efficiency plotted against guide vane opening (one curve for each time)

Weighted average efficiency values

- table:

date (time)	t_1	...	t	...	t_l
weighted average efficiency (η_w), %					

- graphic: weighted average efficiency (η_w) plotted against time

4 Pump efficiency values

for each H_j

– table:

time	t_1	...	t	...	t_l
flow (Q), m^3/s					
power (P), kW					
efficiency (η), %					

– graphic: efficiency plotted against time

Weighted average efficiency values

– table:

time	t_1	...	t	...	t_l
weighted average efficiency (η_w), %					

– graphic: weighted average efficiency (η_w) plotted against time

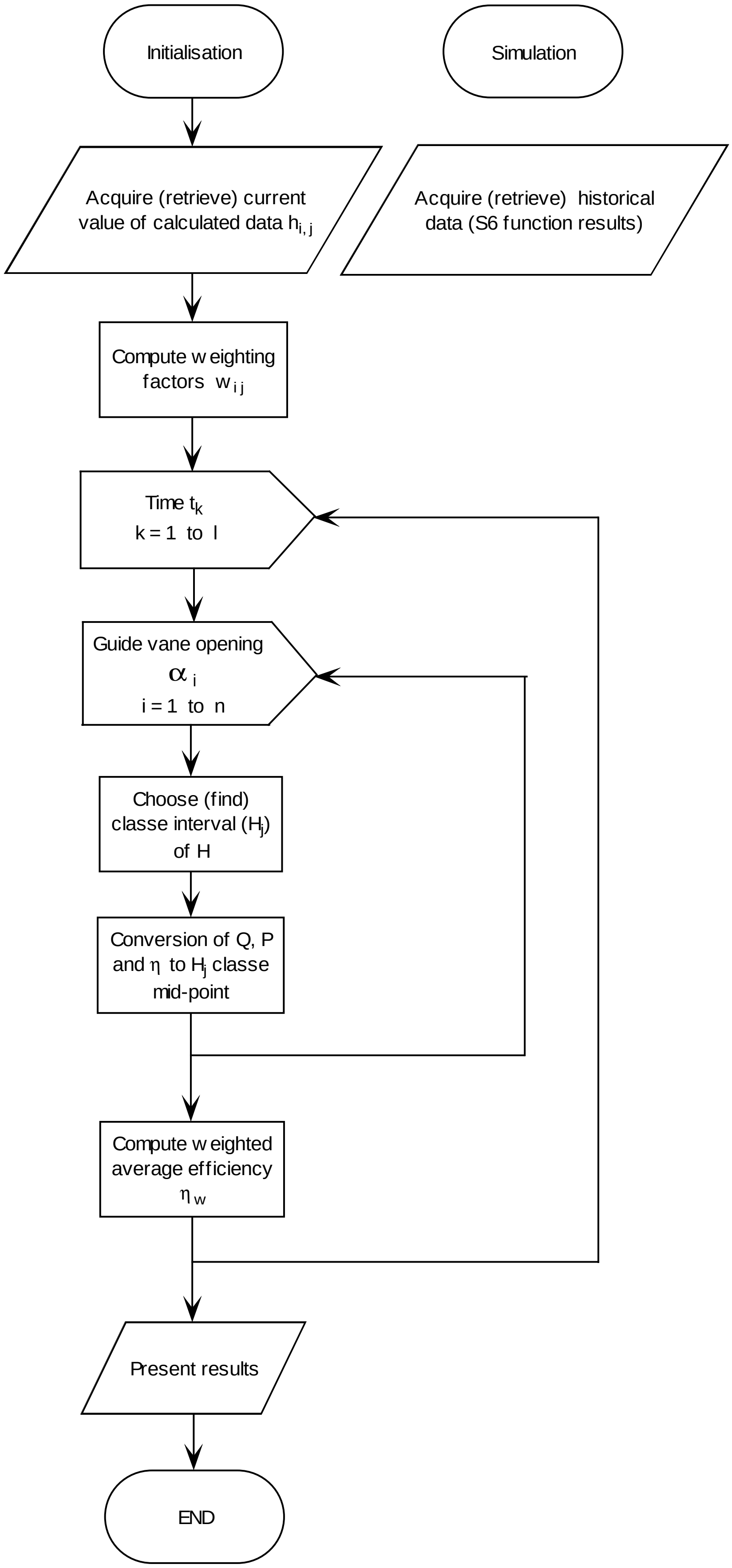
5. DYNAMIC BEHAVIOUR

The function is activated on maintenance operator request .

Operator activation shall be done at sufficiently regular intervals to detect the presence of trends in advance of excessive efficiency degradation.

6. DATA PROCESSING (ALGORITHM)

The overall algorithm is shown on the following figure:


Initialisation
Simulation
Acquire (retrieve) current value of calculated data h i, j
Acquire (retrieve) historical data (S6 function results)
Compute weighting factors w i j
Time tk
k = 1 to l
Guide vane opening
α i
i = 1 to n
Choose (find) classe interval (Hj) of H
Conversion of Q, P and η to Hj classe mid-point
Compute weighted average efficiency
η w
Present results
END

Weighting factor $w_{i,j}$ computation

Weighting factor (relative frequency) $w_{i,j}$ of operating hours class (α_i, H_j) is defined as follows:

$$w_{i,j} = \frac{h_{i,j}}{\sum_i \sum_j h_{i,j}}$$

where $h_{i,j}$ is the absolute frequency (operating hours).

Conversion of turbine operating points quantities to the same head

Conversion of turbine operating points quantities (Q, P and η) to the same head H_j (class mid-point) is made using affinity laws:

$$\frac{Q_j}{Q} = \left(\frac{H_j}{H}\right)^{1/2}, \; \frac{P_j}{P} = \left(\frac{H_j}{H}\right)^{3/2}, \; \eta_j = \frac{P_j}{\overline{g} \cdot H_j \cdot \overline{\rho} \cdot Q_j} \; .$$

Weighted average efficiency calculation

Weighted average efficiency is calculated as follows:

$$\eta_w = \frac{\sum_i \sum_j \eta_{i,j} \cdot w_{i,j}}{\sum_i \sum_j w_{i,j}} \; .$$

7. INTERFACES

Maintenance operator interface shall be capable of display historical data and interact with the associated data base.

System interface to the external world must allow to display the results (tables and graphics) remotely.

8. ERROR MANAGEMENT

Errors manager must display messages describing the cause of an error or a fault: network error, internal error, missing data, ...

9. CONSTRAINTS

To execute correctly the function, a statistical distribution of operating hours by head and guide vane opening classes that represents the operating conditions is needed. This task shall be performed by REMAFEX platform all along machine life through a set of chronometer variables.

Classes interval must be predefined in terms of class mid-point and boundaries for each experimentation site.

10. HARDWARE AND SOFTWARE REQUIREMENTS

The function can be implemented on a standard PC hardware and using standard software, like Microsoft Excel.

The output display should be of the SVGA type and able of presenting colour information.

11. TEST PLAN

It must be possible to test the function independently of data acquisition hardware and in a modular way. The components to test are described in section 6.

Errors cause simulation must also be possible.

12. REFERENCES

[1] IEC 41(1991): Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines

[2] James W. Dally: Instrumentation for Engineering Measurements

[3] EDP/WP4/S6: Compute MSV - Turbine efficiency