DATA TURBINA

CH RUNATULLO II Y III

GCZ INGENIEROS SAC
Enero 2013

DATA TURBINA : RUNATULLO II-III

Descripción

Las características de las turbinas son :

Características Generales

Parámetro	RUNATULLO II	RUNATULLO III
Nº de Unidades	2	2
Tipo de Turbina	Pelton Vertical	Pelton Vertical
Hbruta	330.0 m	426.0 m
Hneta teorica	321.0 m	417.4 m
Q Nominal p/ Unidad	3.5 m3/s	2.70m3/seg.
P Nominal de Turbina	10.0 MW	10.00 MW
Numero inyectores	6 inyectores	4 Inyectores
n velocidad nominal	720 RPM	720 RPM
Deflectores	6	4
Regulación	Inyector	Inyector

Carcaza y Distribuidor:

La Carcaza de la turbina- diseño Rain Power, consta de una sección inferior cilíndrica y una cubierta superior cónica- construida en acero y será embebida en concreto en su posición final. Esta estructura, soportará las presiones del hormigón durante la construcción y el impacto del agua durante la operación. Su construcción será con planchas de acero de alta resistencia ASTM A516, adecuada para estos propósitos.

El distribuidor está constituido por tramos de tubería y bifurcaciones cuya función es la de dirigir el agua hacia los inyectores, penetrando en la carcaza, en una distribución circular alrededor de ella. El distribuidor es diseño Rain Power Noruega, y considera diámetros variables según la posición e ingreso de cada inyector para lograr mayor eficiencia en el conjunto. Su fabricación será en acero de lata resistencia ASTM A516, en secciones y con cambios de dirección de mínimas pérdidas, con refuerzos para anclaje y nervaduras en las bifurcaciones para evitar la concentración de esfuerzos. El conjunto será suministrado en partes para montaje con soldadura y bridas.

El anclaje de la carcaza y el distribuidor será diseñado para permitir dar rigidez adecuada al conjunto, y soportar las cargas estáticas y dinámicas del conjunto para la condición más adversa y finalmente amortiguar las vibraciones, por esto, la carcaza y las tuberías del distribuidor deberá ser llenado con hormigón reforzado, que transmitirá las fuerzas debido a los pesos de las piezas y el torque para las fundaciones.

Rueda Pelton

El diseño de la rueda Pelton Rain Power está basada en la amplia experiencia de Rain , en su efectiva investigación y pruebas de modelos hidráulicos aplicando procedimientos de última tecnología, para lograr una cuchara con forma y superficie eficiente desde el punto de vista del diseño hidráulico, y estructuralmente resistente a los altos esfuerzos a los que es sometido.

La rueda será obtenida a partir de una sola pieza íntegramente forjada en acero inoxidable CrNi 13.4. Las superficies en contacto con el agua, serán cuidadosamente maquinadas y pulidas para ofrecer la minima resistencia al flujo, y su perfil será controlado para asegurar que cumple con las tolerancias. El criterio de aceptación será evaluado según la Norma CCH 70.2.

El montaje de la rueda será de tipo rígido y conectada directamente sobre el eje del generador.

Inyectores y Deflectores

El flujo del agua del distribuidor hacia el rodete se realiza a través del sistema Inyector, conformado por un servomotor hidráulico y aguja móvil. Su montaje es de tipo interno y actúa como órgano regulador de caudal. El movimiento de la aguja será controlado por el regulador de velocidad, siendo la operación de cada inyector independiente para lograr la máxima eficiencia obtenible a la carga parcial correspondiente.

La posición de las agujas serán monitoreadas por sensores de posición lineal montados en los inyectores, y enviarán su señal al gobernador. En caso de pérdida de presión aceite del sistema, el servomotor siempre cerrará los inyectores a velocidad controlada.

Cualquier perdida de aceite o ingreso de agua al sistema hidráulico en el inyector, puede ser claramente observado mediante los indicadores de fuga. Estos indicadores es un sistema de drenaje hacia el exterior de la turbina y se ubican en la parte delantera y posterior del inyector.

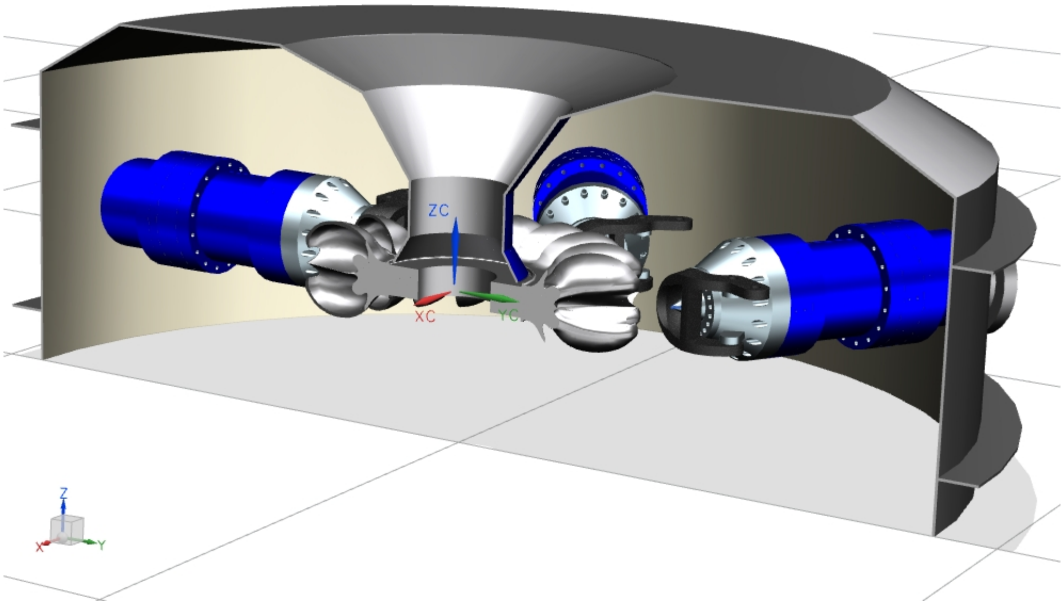
Cada Inyector tiene dispuesto un deflector que desviará el chorro de agua durante cualquier parada de emergencia o súbito retiro de carga. Es importante considerar que solamente es necesario que el deflector corte la mitad del chorro para lograr desviar el flujo del rodete.

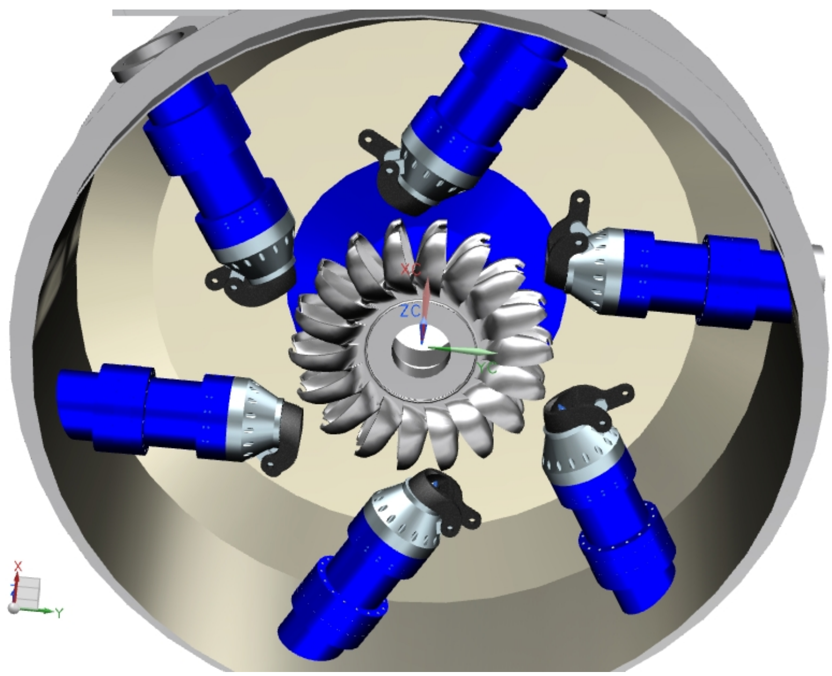
El cuerpo de los inyectores está fabricado en acero de alta resistencia, mientras que las agujas serán fabricadas en acero inoxidable CrNi 13.4, con una punta desmontable (needle tip), los cuales serán debidamente pulidos para una alta eficiencia y larga vida.

Ensamble de la turbina en fábrica.

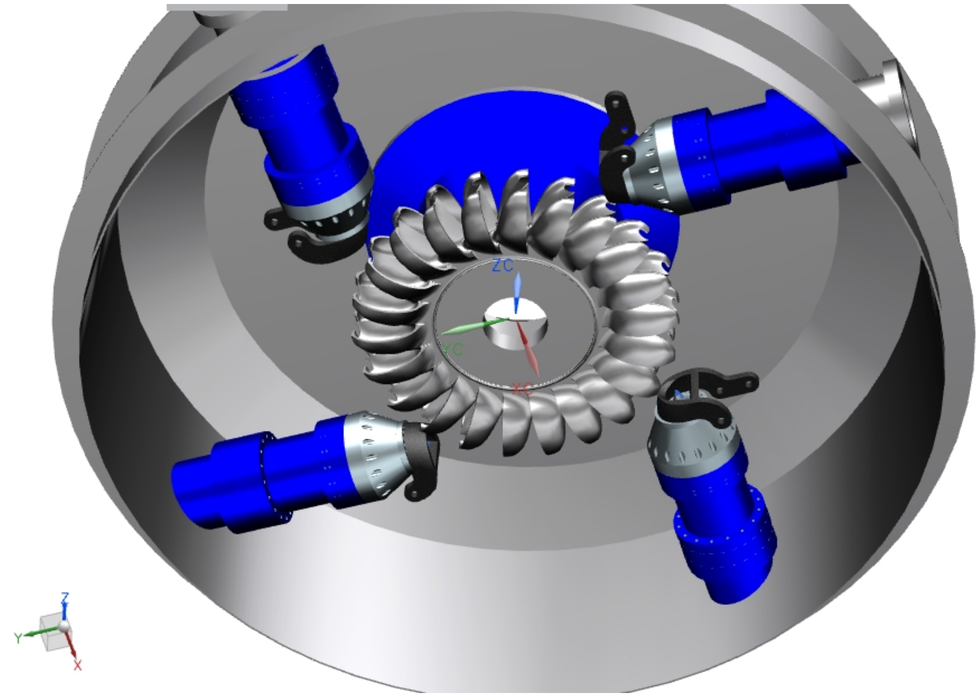
La turbina será completamente ensamblada en fabrica para su inspección y verificación final,, además la secciones de tubería serán sometidas a presión de prueba, así como los inyectores.

Esquemas y Dibujos Runatullo II

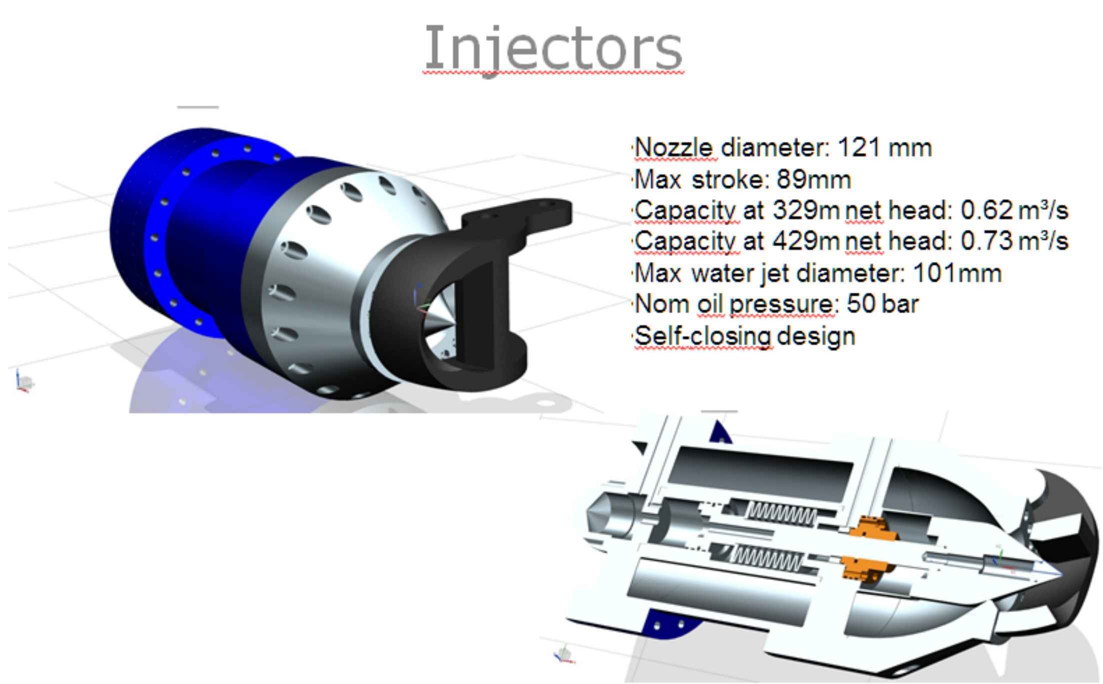




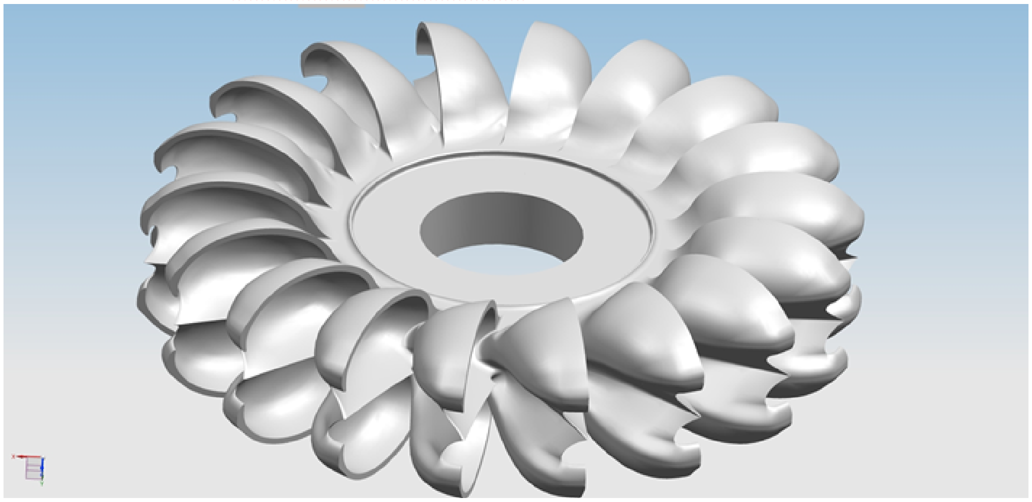
Esquemas y Dibujos Runatullo III



Inyectores

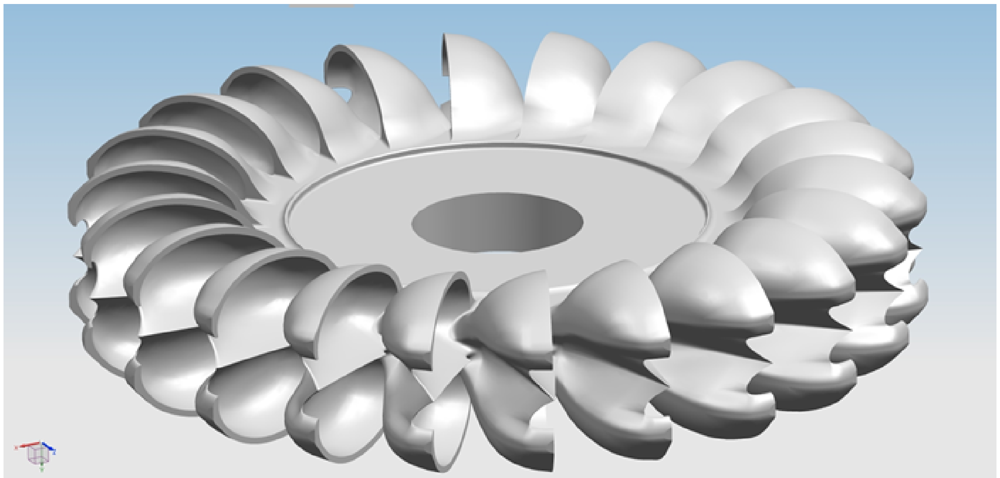


Runatullo 2 Runner



- Pitch diameter: 1000mm
- Bucket width: 329
- Number of buckets: 18

Runatullo 3 Runner

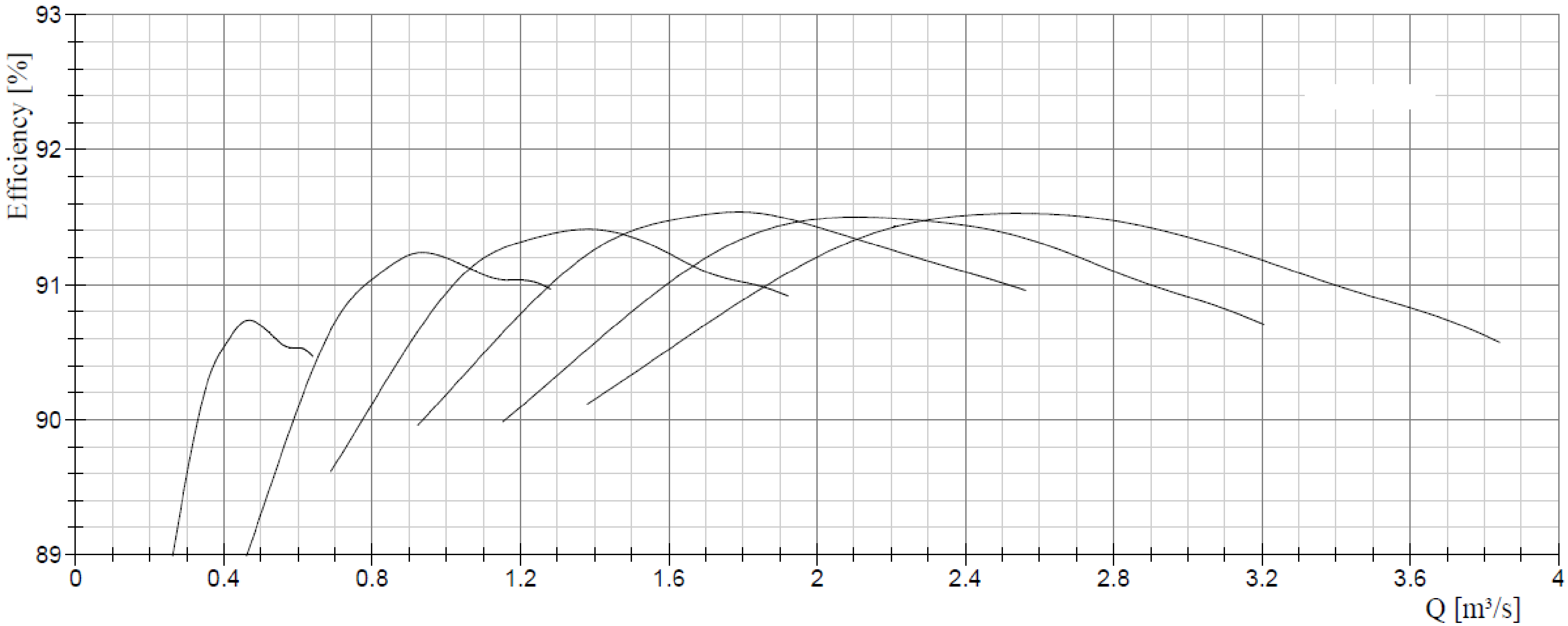


- Pitch diameter: 1178mm
- Bucket width: 321
- Number of buckets: 22

RAINPOWER

Dokumentnavn / Document name

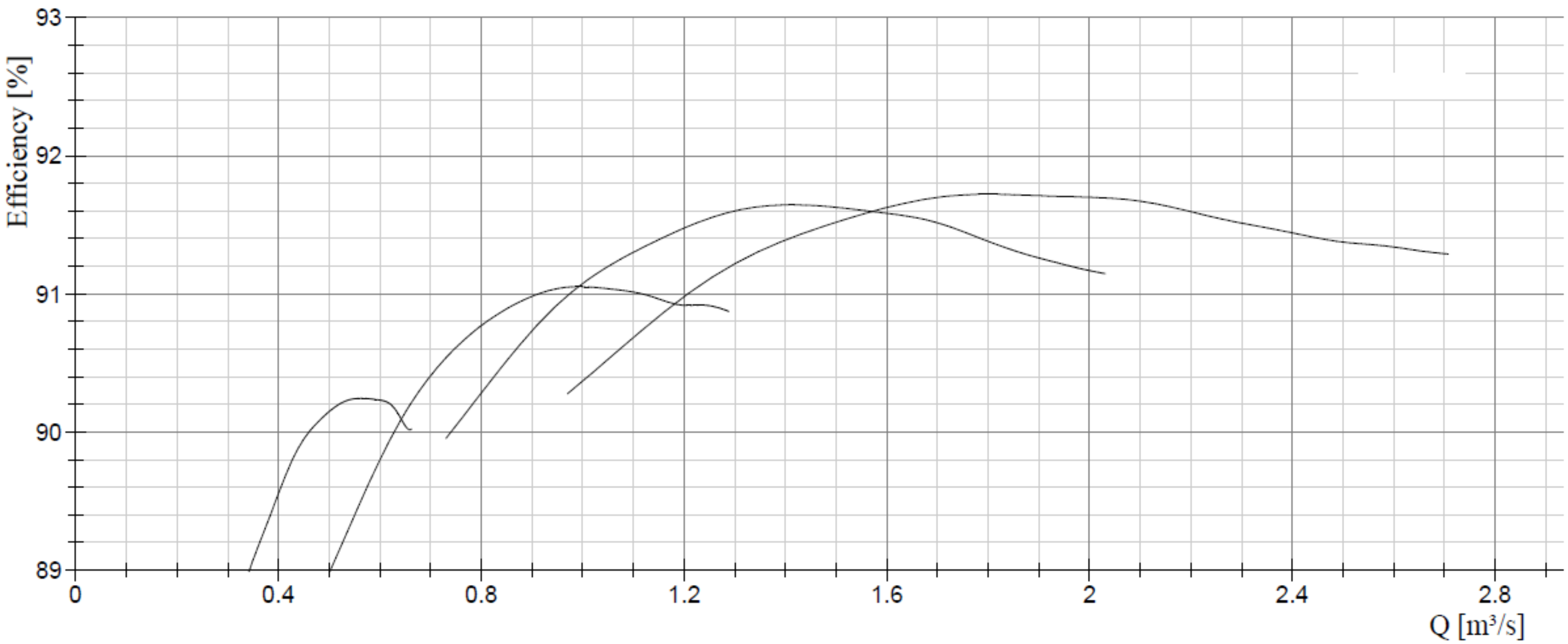
Ordre nr. / Order no.	Kunde / Customer Hidro Santa Cruz - Runatullo 2	Side / Page 1 av / of 1
Dato / Date 2012-02-10	Sak / Subject Q_r=3.5m³/s,n=720rpm, Efficiency based on Model test Scaled in accodance with IEC 60193(T=10° C)	Dok. nr. / Doc. no. - Rev. 23556 - 0
Sign. Hallvard Meland		Rapport nr. / Report no.



RAINPOWER

Dokumentnavn / Document name

Ordre nr. / Order no.	Kunde / Customer Hidro Santa Cruz - Runatullo 3	Side / Page 1 av / of 1
Dato / Date 2012-03-12	Sak / Subject Q_r=2.7m³/s,n=720rpm, Efficiency based on Model test Scaled in accodance with IEC 60193(T=10° C)	Dok. nr. / Doc. no. - Rev. 23557
Sign. Hallvard Meland		Rapport nr. / Report no.



Data y constantes para regulación RUNATULLO II.

Datos	Turb-Gen	unidades	Notas
Qn	3.5	m3/s	Por turbine
Hn	320.3	M	
Pn	10.0	MW	
GD2	11.0	Ton-m2	
Ta (at net head and flow)	1,55	S	
n	720	Rpm	

DATOS DE REGULACION RUNATULLO II

No	Flow (m3/s)	Net head (m)	Output (MW)	Speed (rpm)	GD2 (t-m2)	Ta (s)	Tw (s)	Ta/Tw	Ta/Tw
1-2	3,5	320,3	10	720	11	1,55	0.36 – 0.68s	4.30	< 6

Data y constantes para regulación RUNATULLO III

Datos	Turb-Gen	unidades	Notas
Qn	2,7	m3/s	Por turbina
Hn	419,9	M	
Pn	10.0	MW	
GD2	11.0	Ton-m2	
Ta (at net head and flow)	1,54	S	
n	720	Rpm	

DATOS DE REGULACION RUNATULLO II

No	Flow (m3/s)	Net head (m)	Output (MW)	Speed (rpm)	GD2 (t-m2)	Ta (s)	Tw (s)	Ta/Tw	Ta/Tw
1-2	2,7	419,9	10	720	11	1,54	0.36 – 0.68s	4.28	< 6

5 TECHNICAL SPECIFICATION

5.1 Standards

5.1.1 Turbine governor standards

The HYDROTROL®1x governor conforms to the following standards:

IEC 61362 – 1998	Guide to specification of hydraulic turbine control systems.
IEEE Std. 125-1988	Recommended Practice for Preparation of Equipment Specification for Speed-Governing of Hydraulic Turbines Intended to Drive Electric Generators.

The HYDROTROL®1x governor is tested according to:

IEC 60308 - 1970	Guidelines for testing of governing systems for hydraulic turbines.

The governor is designed to fulfill the Norwegian demands for turbine governors, as described in the following documents:

Statnett:	”KtA: Retningslinjer for tekniske krav til anlegg i norsk hovednett.”
Statnett:	”Spesifikasjon for krav til turbineregulatorer i norske vannkraftaggregater.”

5.1.2 EMC and environment requirements

The HYDROTROL®1x governor conforms to the following standards:

EMC:	Emission	EN 50081-2
	Immunity	EN 50082-2
Electrical safety:	EN 60950	
Isolation:	Dielectrical test	IEC 255-4, 2KV, 50Hz 1min.
Temperatur and humidity:	IEC870-2-1 kl. C	
	Surrounding temp.	0 – 55 °C.
	Humidity	< 85% RH at 25ºC.

5.2 Governor data

Load and frequency setpoints are changed using ramp functions. The ramp speed can be defined individually.

The load can be selected by adjusting the load setpoint, either as a power setpoint which is converted to an opening setpoint by means of the P/Y-curve or directly as a given opening.

Ramp time adjustment: 0.1 – 10 % / seconds

5.2.1 Frequency control

The frequency control can have power linearization which provides power response to the PID controller. Without linearization, the provided response will be as a change in turbine opening.

With power linearization, droop defines the static relation between frequency and power.

Without power linearization, droop can be defined either as the static relation between frequency and opening or as the static relation between frequency and power.

Regulator type	PID
Number of parameter sets	4 (disconnected mode, normal grid mode, disturbed grid mode, isolated grid mode) Automatc grid detection.
Opening dependent parameters	Integral time and gain in normal- and isolated grid mode can be made linear proportional to the opening.
Proportional gain, Kp	0.1 – 20.0 x
Integral time constant, Ti	0.1 – 20.0 sec. (Integral gain Ki = Kp/Ti)
Derivative time constant, Td	0.0 – 5.0 sec. (Derivative gain Kd = Td•Kp)
Time constant for the derivative filter, Tf	0 – 1.00 sec.
Frequency droop	0 – 10.0%
Max. deadband at nominal frequency	0.005%
Min. Frequency controller sensitivity	0.0025%
Electronic governor response time	max 0.04 sec. (Max response time from a frequency change to a changes on the analog output)

Note. 1: The given ranges are normal adjustment ranges. The parameters can be set outside these limits.

Note. 2: Terminology in earlier standards.
Kp = 1/bt (bt: Transient droop)
Ti = Td eller Tn (Integral time or attenuation)
Td = Tv (Derivative time)
Droop = bp = bs (stationary droop or only droop)

5.2.2 The stabilizing functions WCC and PFB

If the dynamic characteristics of the water conduit system make frequency control difficult, an additional influence can be used from one of two different stabilizing functions.

- WCC, Water Column Compensation.
- PFB, Pressure Feed Back.

WCC: Water Column Compensation is an internal feedback in the regulator modefying the characteristics of the PID regulator.

PFB: Pressure Feed Back requires a high quality pressure measurement using a high bandwidth, high resolution transducer installed in the turbine inlet. PFB wil improve the stabillity margins with little deterioration of the response to frequency deviation.

Transferfunksjon:

$$H_{FB}(s) = B_W \frac{T_0 \cdot s}{(1 + D_0 \cdot s) \cdot (1 + D_1 \cdot s) \cdot (1 + D_2 \cdot s)}$$

Proportional gain, Bw (This can be made dependant apon opening)	-10.0 – 10.0 x
Time constants T0, D0:	0.10 – 10.00 sek.
Time constants D1, D2:	0.00 – 10.00 sek.

The mathematical model of the PID and the stabilizing functions is shown in appendix A.

5.2.3 Opening control

During opening control the load are changed from the load setpoint. The frequency controller is not active.

Regulator type	No regulator, positioning of turbine opening.

5.2.4 Power control / power optimization

Active frequency control is optional. For power control, the power is changed with the load setpoint. The load setpoint is converted to opening using the P/Y-curve. Deviations between the actual P/Y-relation and the curve measured at commissioning is handled by the controller.

Power optimization:

If power optimization is active, the deviation will be corrected, once, a given period of time after a load change or at the next setpoint received.

Continous regulation:

Controller type	I-regulator modefying the P/Y curve gain to compensate changes in head and curve deviation.
Integral time constant, Ti	30 – 300.0 sek.
Max. deadband	0.2%
Min. load controller sensitivity	0.1%

Note: The given ranges are normal adjustment ranges. The parameters can be set outside these limits.

5.2.5 Water level control

The water level is regulated to the water level setpoint. The frequency controller is off. The water level droop is defined as the static relation between water level and servo position.

The control loop can be linearized with regards to the rate of flow by means of a Q/Y-curve.

Controller type	PID
Proportional gain, Kp	0.1 – 20.0 x
Integral time constant, Ti	10 – 3600 sec.
Derivative time constant, Td	0.0 – 500.0 sek.
Time constant for the derivative filter, Tf	0 – 150.00 sek.
Adjustable deadband	0 – 10.0%
Max deadband	0.025%
Min. sensitivity for the controller	0.015%

Note 1: Max deadband and min sensitivity is given for a high resolution transducer with adjustable deadband at zero.

Note 2: The given ranges are normal adjustment ranges. The parameters can be set outside these limits.

5.3 Process interface

The I/O-interface of the HYDROTROL®1x includes: RMT, SM and PLC (HYDROTROL® 11 og 12).

5.3.1 Process specific I/O-signals located on the RMT

Includes transducer and measurement system for the following signals.

- Frequency measurement, mechanical rpm

Type of measurement	One or two inductive transducers reading a segment disc.
Pulse frequency, 1 transd.	0.1 – 20 x Fn
Pulse frequency, 2 transd.	Fn (Nominal frequency)
Signal standard	DIN 19 234 (NAMUR)
Freq.range calibrated measure	0 – 160 Hz
Resolution	0.005%
Accuracy	0.01%

- Frequency measurement, generator terminal voltage

Type of measurement	Based on detecting voltage zero crossings
Nominal voltage	100 – 120V, 50 or 60Hz 1-phase.
Frequency range	10 – 160 Hz
Resolution	0.005%
Accuracy	0.01%
Sensitivity	Active from approx. 0.4%, 0,4V remanence voltage

- Bus bar voltage

Type of measurement	Based on detecting voltage zero crossings
Nominal voltage	100 – 120V, 50 or 60Hz 1-phase.

Frequency range	10 – 160 Hz
Resolution	0.005%
Accuracy	0.01%
Sensitivity	Active from approx. 5%, 5V.

- Generator voltage

Type of measurement	1-phase
Nominal voltage	100 – 120V, 50 or 60Hz 1-phase.
Accuracy	±0.5%

- Bus bar voltage

Type of measurement	1-phase
Nominal voltage	100 – 120V, 50 or 60Hz 1-phase.
Accuracy	±0.5%

- Angle between generator and bus bar voltage

Type of measurement	Based on detecting voltage zero crossings
Accuracy	max. deviation ±3°, typical ±1°
Resolution	0.1°

- Generator power

Type of measurement	Requires external transducer.

- RM module 2 analoge inputs

Application	Position feedback, water level, power from external transducers
Signal standard	Bipolar -10V - 0 – +10V.
Range	0 – 100%, software calibration
Resolution	10 bits and 10 times over sampling, minimum 0.1% resolution.

- RM module 2 analoge outputs

Application	Control signal(s) for servo motor(s), remote indicator
Signal standard	±75mA, ±20 mA, 0 – 20mA, 4 – 20mA, ±10V, 0 – 10V.
Range	Offset and gain are calibrated in software
Resolution	11bit bipolar signals 0.05%, 10 bit unipolar signals 0.1%
Dither signals	0 – 25Hz, 50 or 100Hz can be added to the output utilized for servo operation.

- SM module 8 analog inputs

Application	Position feedback, water level, power from external transducers
Signal standard	0 – 20mA, 4 – 20mA, 0 – 10V.
Range	0 – 100%, software calibration
Resolution	12bit, 0.025% + overrange approx. 10%.

- SM module 8 analog outputs

Application	Control signal(s) for servo motor(s), remote indicator
Signal standard	±75mA, ±20 mA, 0 – 20mA, 4 – 20mA, ±10V, 0 – 10V.
Range	Offset and gain are calibrated in software
Resolution	11bit bipolare signals 0.05%, 10 bit unipolar signals 0.1%
Dither signals	0 – 25Hz, 50 or 100Hz can be added to the output utilized for servo

operation

- 8 digital inputs

Signal type	Optical isolated binary inputs
Auxilary voltage	24V, supplied from the HYDROTROL® 1x

- 9 digital outputs utganger

Signal type	Relay terminals with no potentila
Terminal data	$300V_{dc}$/ 50W resistiv load, $250V_{ac}$/ 2 KVA

5.4 Communication

Fieldbus — Several communication protocols are available for the different HYDROTROL® 1x editions. Availability depends on the version. The following protocols are available:

- IEEE 802.3 (Ethernet)
- PROFIBUS DP/DP-V1
- FOUNDATION Fieldbus
- RS232 based protocols, e.q. Modbus RTU, 9600 baud serial bus. Modicon Modbus protocol point-to-point

Conventional interface — Analoge and digital signals

5.5 Power supply

The powersupply is internally converted to 24VDC, which is the main source of power for the governor.

External power supply	110 / 220 VDC, 110 / 230 VAC
Power consumption	< 100 W, typical 40W

Redundant power supply is optional.