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FLOW MEASUREMENT BY WINTER KENNEDY METHOD IN LIFT IRRIGATION SCHEME PUMPS

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ABSTRACT

Winter Kennedy method [1] is an index method to measure relative discharge generally used in Hydro Turbines. It is customary to provide Winter Kennedy taps in Hydro Turbines to provide user with relative discharge and hence the efficiency. The trend in efficiency is analyzed to assess the requirement of refurbishment of the turbine. One of the many applications of Winter Kennedy method is continuous discharge monitoring.

Relative discharge measurement is even more relevant in case of Lift Irrigation Scheme pumps where the output is the quantity of water pumped at a particular head. Clause no 15.2.1.1 of IEC 60041:1991 [2] states that the Winter Kennedy method is applicable on turbines only. In this work, applicability of Winter Kennedy method for continuous discharge monitoring for Lift irrigation Scheme pumps is studied.

Experiments were conducted on single Pump model (specifically designed for Lift irrigation schemes generally working close to duty point) at the Hydro laboratory as per IEC 60193:1999 [3]. Two sets of taps were made in the model, one set of taps in spiral (Winter Kennedy) and other set of taps in Draft Tube cone (Converging section). Results from two set of taps were compared. Results revealed that Winter Kennedy taps are suitable for Francis Pumps/ Pump turbines in Pumping operation (except for very low discharges during pumping).

INTRODUCTION

Winter Kennedy relative discharge measurement is not applicable for pump operation as per IEC 60041:1991 [2] and ASME PTC 18-2011 [4], though Winter Kennedy taps are used frequently in turbine operation for relative discharge measurement. With the advent of new SCADA systems, Winter Kennedy index method serves as continuous discharge measurement in power plants. When common errors associated with the use of Winter Kennedy method are addressed carefully, it serves as a very convenient and cost effective method of relative discharge measurement [5]. Author's experience has shown that many Pump house managers are keen on knowing the discharge while the unit is in pumping operation. Real time information regarding discharge will enable pump managers to operate the pump house efficiently. This along with increasing number of Lift Irrigations Schemes in India, led authors to investigate the applicability of Winter Kennedy method in Pumping operation. Many such lift irrigation schemes are under commissioning, on which relative discharge would be measured using Winter Kennedy method and results would be reported.
IEC 60041:1991 [2] has recommended that suitably located taps in the suction tube may be used for measurement of differential pressure in case of pumps. Therefore one set of taps (Winter Kennedy) were provided in the Spiral Casing (Fig.1) and other set of taps were provided in draft tube cone (Fig.2).

This paper compares the applicability of pressure taps located in spiral casing to that of the pressure taps located in the draft tube cone for Lift Irrigation scheme pumps.

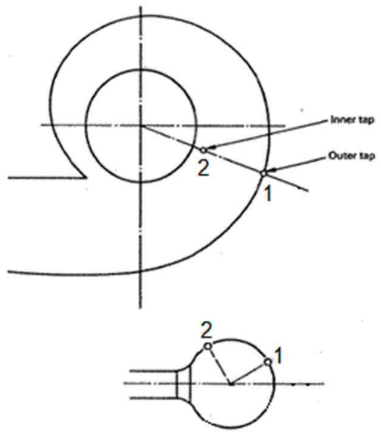

Figure 1-Winter Kennedy Taps in Spiral Casing (1, 2)

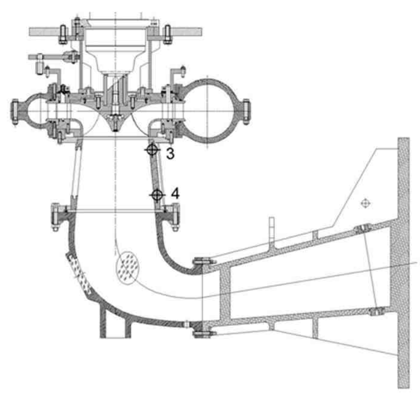

Figure 2-Index Taps in Draft Tube Cone (3, 4)

MATERIALS AND METHOD

Differential Pressure Measurement Equipment

Experiments were conducted in Hydro laboratory of Centre of Excellence- Hydro Machines. Pump model was installed on the Test bed-03. Differential Pressure for index was measured using GE UNIK 5000 series differential pressure transducer. Signals from differential pressure transducer were acquired by National Instruments cDAQ along with NI 9219 universal card. Additionally Flow was measured using Endress Hauser make Electromagnetic flow meter mounted in the water loop.

Method

The pump model was run in pumping mode to generate required test head. Various flow points were set with the help of Energy Dissipater. Every time after adjusting the energy dissipater opening, the flow conditions were allowed to stabilize. For each such stable point, readings of flow and differential pressure from Winter Kennedy taps and index taps on Draft tube cone were taken and it was checked if the points follow the equation 1.

$$Q = k \, . \, \Delta P^{n} \qquad - (1)$$

Where,

Q is discharge through pump
ΔP is differential pressure.
k and n are constants.

Results of Experiment

Winter Kennedy taps (in spiral casing)

It is observed that discharge vs differential pressure follows equation (1), with k= 0.8969, n = 0.5030. It can also be seen that points with lower discharge did not lie on this curve. Exponent value n is very close to the theoretical value of 0.5. Table 1 gives the percentage error between actual discharge and relative discharge calculated from the curve using differential pressure value for Winter Kennedy method. Fig 3 illustrates the relation between discharge and differential pressure between Winter Kennedy taps in spiral casing.

Table 1-Relative discharge measurement by Winter Kennedy method

Winter Kennedy Method					
Rec No	Normalized Discharge	Transducer Reading	Differential Pressure	Calculated Normalized Discharge	Error
	m^3/s	V	mWC	m^3/s	%
301	1	5.62614	1.230598	0.99557	-0.44
302	0.96966	5.59784	1.172763	0.97175	0.22
303	0.93631	5.55787	1.09108	0.9371	0.08
304	0.89451	5.51315	0.999689	0.89676	0.25
305	0.84718	5.46089	0.89289	0.84722	0
306	0.80362	5.41819	0.805627	0.80451	0.11
307	0.75912	5.37602	0.719448	0.76	0.12
308	0.71924	5.33632	0.638316	0.71561	-0.5
309	0.64188	5.27702	0.51713	0.6437	0.28
310	0.69161	5.31497	0.594685	0.69057	-0.15
311	0.59631	5.24682	0.455412	0.60384	1.26
312	0.53958	5.23314	0.427456	0.5849	8.4
313	0.4736	5.1852	0.329485	0.51312	8.34

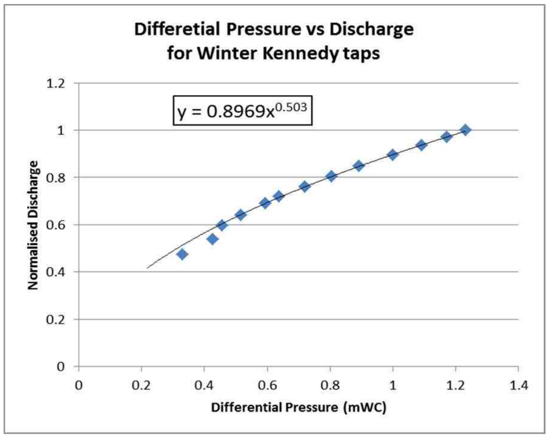

Figure 3-Curve for Winter Kennedy method

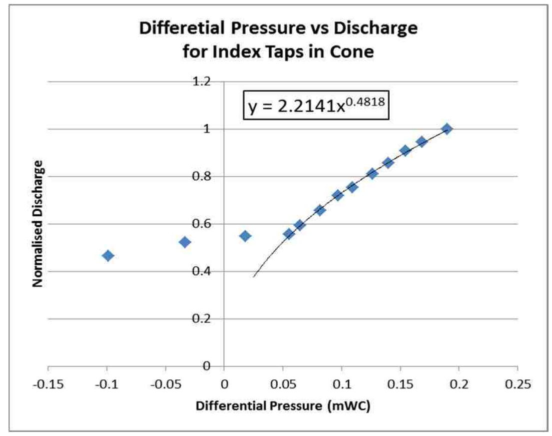

Figure 4-Curve for Index method

Index taps (in draft tube cone)

It is observed that discharge vs differential pressure also follows equation (1), with k= 2.2141, n = 0.4818. It can also be seen that points with lower discharge did not lie on this curve. Exponent value n is very close to the maximum limit prescribed by IEC 60193:1999. Table 2 gives the percentage error between actual discharge and relative discharge calculated from the curve using differential pressure value for Index method (taps in draft tube cone). Fig 4 illustrates the relation between discharge and differential pressure between Index taps in draft tube cone.

Table2- Relative discharge measurement by Index method (taps in Draft tube cone)

Index Method					
Rec No	Normalized Discharge	Transducer Reading	Differential Pressure	Calculated Normalized Discharge	Error
		V	mWC		%
288	1	5.11699	0.190089	0.99494	-0.51
289	0.94515	5.10632	0.168284	0.93822	-0.73
290	0.90638	5.09958	0.15451	0.9004	-0.66
291	0.85675	5.09248	0.14	0.85862	0.22
292	0.81042	5.08572	0.126185	0.8167	0.77
293	0.754	5.07737	0.109121	0.76149	0.99
294	0.71758	5.07145	0.097023	0.71957	0.28
295	0.6548	5.06404	0.08188	0.66308	1.26
296	0.59331	5.05565	0.064734	0.59211	-0.2
297	0.55581	5.05096	0.055149	0.54811	-1.39
298	0.54666	5.03275	0.017935	0.31903	-41.64
299	0.52234	5.00769	-0.033278	-	-
300	0.46453	4.97577	-0.09851	-	-

Discussion

Results from both the relative discharge measurement method is compared on following points

- For both Winter Kennedy taps and Index taps relation between discharge and differential pressure follows eqn 1 (except very low discharges). Also for both the cases value of exponent n is between 0.48 and 0.52 as per IEC 60193:1999, though it is close to the theoretical value of 0.5 in case of Winter Kennedy taps in spiral casing.
- In both the cases, points with very low discharge did not follow the curve as can be seen from the Fig.3 and Fig.4. However in case of Lift Irrigation Pump schemes, machine selection is done near 0.75 normalized discharge value. Also discharge variation for a particular plant (depending upon head variation) varies such that normalized discharges lower than 0.6 are never achieved. Hence it can be deduced that pump would operate considerably close to the duty point discharge. Therefore it can be deduced that both relative discharge measurement method would work well in the operation zone.
- Differential pressure is considerably more between Winter Kennedy taps in spiral casing as compared to that between Index taps on cone. This would have an impact on the differential pressure measurement accuracy at site.

Conclusion

With this work following conclusions can be drawn.

- Winter Kennedy taps perform well during pumping operation for Lift Irrigation schemes within their operating zones. This method can be used for relative discharge measurement for such schemes.
- Differential pressure between Winter Kennedy taps in spiral casing was significantly higher than that between Index taps making Winter Kennedy method preferable over Index method with taps in draft tube cone.

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BIODATA

Name	: Rakshit Koranne
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Area of Expertise

I have Eight years of experience in Hydro machine model testing and Field testing. Over these years I have conducted 14 development model tests, 6 Contractual witness model tests and 6 Field acceptance tests as team leader. Other than this I have been part of many model/field acceptance test team. This work involved calibration of sensors, data acquisition and analysis.

Significant Achievements

- Developed guide vane calibration system for instrumented guide vanes.
- Successfully executed Capital Investment Project "Augmentation of Hydro Machine Test facility". Contributed in design of piping layout as per BHEL standards/relevant IS, preparation of specifications for instruments and procurement & Erection of items/instruments. Awarded letter of recognition for this work in BHEL Excel awards 2015.
- Developed software on NI LabVIEW platform for Frequency analysis of Pressure pulsation signals acquired from Draft tube cone of water turbine. Copyright application has been filed for this software.

Professional memberships

NIL

Papers published in journals and conferences

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