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The Effect of Speed Smart Control System SSCS on the Performance of Hydropower System

Abstract*-In this work, the speed smart control system is designed and implemented to improve and enhance the performance of hydropower system, where Arduino Uno R3 microcontroller is used for this propose. The speed smart control system is used to control the volume flow rate of water with respect to the load applied to the Pelton turbine shaft at optimum range of speed. Using nozzle outlet diameter of 8.87 mm. A water pump is used to generate the volume flow rate and pressure head. The results show that the maximum reduction in the hydraulic power was observed at zero torque, where the percentage reduction in the hydraulic power was equal to 87.33% when using speed smart control system. Also the optimum torque for maximum brake power and efficiency of Pelton turbine system have been increased when using a speed smart control system, where the percentage increasing was about 28.15%.Comparing result with and without using smart control system shows the percentage increased in the brake power and efficiency of Pelton turbine system were 26.3% and 35% respectively at the optimum torque for maximum brake power and efficiency of Pelton turbine system. Time response was four seconds to achieve a steady state for the rotational speed of Pelton turbine.*

Keywords- *Pelton Turbine, Water Pump, Electrical Power, Arduino Uno*

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1. Introduction

The Electricity power considered as very important in the world and especially in the Iraq country due to higher temperature during the summer [1]. The hydropower plant is one of the important sources of the renewable energy of the worldwide to generate the electricity. The percentage-generated energy by a hydropower was equal to 86.31% of the total renewable energy resisted by the international energy agency at 2012 [2].The Pelton turbine is one of the most important part of the hydropower plants, which a type is of impales water turbine. In the 1870, the Pelton turbine was invented by luster Allan Pelton [3]. Niranjan et al. [4] developed a method to control the speed of control an induction motor. They were used an open loop phase control by using the Arduino controller. They were controlled the speed of induction motor could be controlled by using Arduino to controlling the pulses. Paul [5] implemented a persistence of vision a design based on advance microprocessor (Arduino duemilanove). They used Arduino due Milan one board because of higher speed at operation, easy to used lower power motor, and low cost than others microcontroller. The results shown that the display was extremely attractive to look and give a sense of being a transparent display. Neerparaj and Bijay [6] developed a closed loop control system to control the speed of DC motor. They were used ATmega168 Arduino microcontroller. The results show that the system outputs were graduate with that obtained from the theoretical results. The Pelton turbine is type of an impales turbine, which convert the potential energy into the kinetic energy. There many papers have been published in the last decades about experimental and numerical analysis and design of Pelton turbine [7-19] to improve the performance and development of Pelton turbine. In addition, there are many papers have been published to study numerically and experimentally the performance of the nozzle which used in the hydropower [20-28]. The objective of the present work is to investigate experimentally the effect of the speed smart control system on the performance of the hydropower system. The speed smart control system is used to improve and enhance the performance of hydropower system, where Arduino Uno R3 micro controller was used for this propose.

2. Theory

The discharge of water, the torque applied on the turbine shaft and water head are the main parameters that effect the performance of

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hydropower system. The volume flow rate) discharge) of the water is using to calculated [29].

$$Q = \frac{V}{t}$$

(1)

The input hydropower applied to the Pelton turbine is evaluated as:

$$ph = \rho g H Q$$

(2)

The following equation is used to find the torque on the wheel of Pelton turbine:

$$T = (F1 - F2)R$$

(3)

The power produced by the Pelton turbine (brake power) is:

$$Pb = T \times \omega$$

(4)

The efficiency produced by the hydropower system is determined as:

$$\eta = \frac{Pb}{Ph} \times 100\%$$

(5)

3. Experimental Work

A test rig of a Pelton turbine system was designed and implemented as shown in Figures 1 and 2 show the speed smart control system used, where the experimental works were carried on it with nozzle of outer diameter of (8.78) mm. The system consists of Speed Smart Control System SSCS, Pelton turbine with 24cup buckets of the tip diameter of (269.89) mm and hub diameter of (221.29)mm as shown in Figure 3,water pump, digital flow meter, tachometer, and tension scale gauge. A water pump was used to generate volume flow rate and the pressure head.

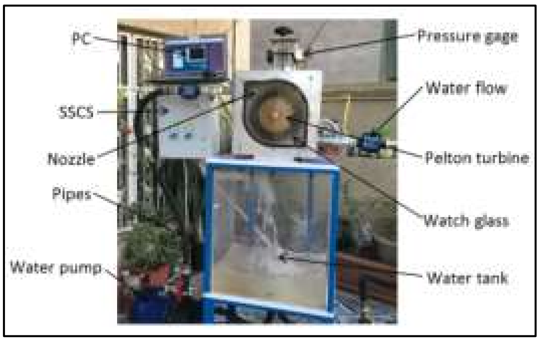

Figure 1: hydropower system

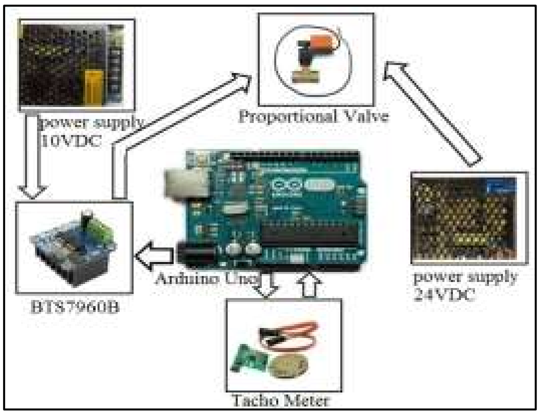

Figure2: Speed Smart Control System (SSCS)

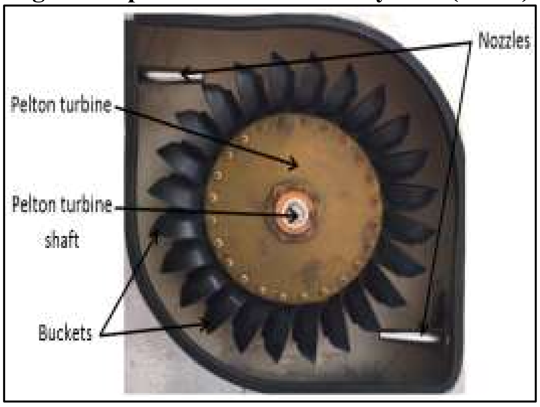

Figure 3: Pelton turbine

4. Results and Discussion

The experiment include a comparative study between Pelton turbine performance with and without a smart control system SSCS using nozzle with outlet diameter of (8.78mm). The controlled speeds of the Pelton turbine were between 530 and 585 (rpm), where the maximum values of brake power and efficiency were obtained at this range of speed. Fig.4. show the speed response of Pelton turbine with the torque equate to zero, where speed over shot from zero to 1400 rpm and then decreased towered the average value of the speed setting in about 4 seconds, when the control value rotated to partially closed the value and reduced the volume flow rate of the water. Fig.5. shows the speed response of Pelton turbine when increasing the torque where the speed curve was oscillated between the 40 and 50 seconds and then settled of the average value the controlling speed. Figures 6 to 13 show the comparative test results for Pelton turbine performance as a function of torque (load) applied on the turbine shaft with and without using smart speed control system. Figure 6 shows the volume flow rate was constant in the case of without using a control system, while in the case of using control system the volume flow rate has been variable, which has a lower value at zero torque and increase when the torque increases until reach a certain value approximately equate to 1.29 N.m then the volume flow rate follow behavior without control system as shown in Figures 5 to 12. In the case of using a control system there is large save of amount of mass of water at lower applied load on the turbine shaft. The percentage decreased in the volume flow rate at zero torque is about 52.54% in case of using a control system comparing without using control system. Figure 7 shows the hydraulic power (input power) of the water equal constant value the in case of without using control system, because of constant volume flow rate and lead of water. While the hydraulic power is variable in the case of using control system due to the variable values volume flow rate of water head as shown in Figure 6 and Table 1. The maximum percentage reducing in the hydraulic power is approximately equal to 87.33% at zero torque. Figures 8 and 9 show the performance characteristic of Pelton turbine without and with using control system. The figures show the control system were improved and enhances performance for Pelton turbine by using the control system. Fig.8. shows that the maximum brake power was increased in the case of using control system, which enhances performance for the Pelton turbine due to the working conditions at the speed of optimum torque for maximum brake power and efficiency. Figure 9 shows the improvement in the efficiency of the Pelton turbine in the case of using control system when the torque less than 1.4 N.m. This is because of reduction in the hydraulic power due to their action of control system, where the maximum efficiency in the case of using a control system was about 57.7%, while in case of without using a control system was about of 37.5%. Figures 10 to 13 the relation of speed of Pelton turbine and the performance characteristic of Pelton turbine system without and with using control system, where the setting speed for controlling system where between 530 and 585 (rpm). These figures show there are three regions of variation of the curves with respect to the rotational speed of the Pelton turbine .the first region is of constant rotational speed at the optimum torque for maximum brake power and efficiency of Pelton turbine system. The second region is between the constant rotational speed and 200 rpm. While the third region is between 200 and zero rpm, which follow the performance characteristic of Pelton turbine system without using controlling system. In this case the Pelton turbine system because out of control. Fig.10. show the behavior of torque with respect to the rotational speed control system and turbine by using a control system. In the case of without using control system the torque distribution is linearly with respect to the rotational speed (zero torque at maximum speed and maximum torque with zero rotational speed). While in the case of using control system, the torque was distributed along the constant rotational speed of Pelton turbine at the optimum torque for maximum brake power and efficiency in the first. While the torque distribution in the second and third regions become linearly as show in the Figure 10, any increase in the torque lead to the reduction in rotational speed of Pelton turbine. Also the figure show that an improvement and enhancement in the torque in the first and second regions, where the optimum torque for maximum brake power and efficiency was increased from 0.92675 N.m for without control to 1.29N.m (the percentage increasing in the torque was 28.15%). This improvement led to improve in the brake power and efficiency of Pelton turbine system as shown in Figures 11 and 12. Figure 13 shows the volume flow rate distribution for by using control system and without using control system with respect to rotational speed of Pelton turbine. In the case of without using control system the volume flow rate was constant and had a value of 5.9 l/min. This was indicated a large saving in the water consuming for the required torque. Where the percentage saving of water volume flow rate was 52.54% for using control system at zero torque. Figures 12 and 13 show the improvement and enhancement of the Pelton turbine system by using a smart speed control system especially at the first region of variation due to increase in the optimum torque and reduction in hydraulic power as explained previously. Where the percentage increasing in the brake power and efficiency of Pelton turbine were 26.31% and 35% respectively at optimum torque for the maximum brake power and efficiency of Pelton turbine system.

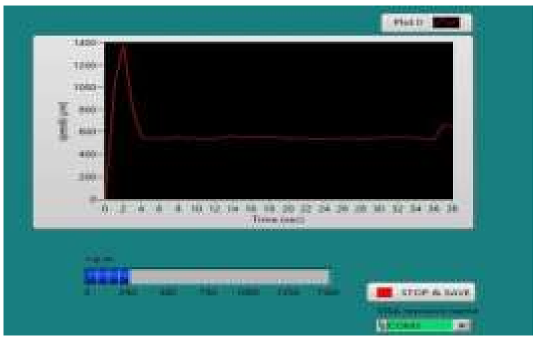

Figure4: Pelton turbine speed response by using speed smart control system with zero torque

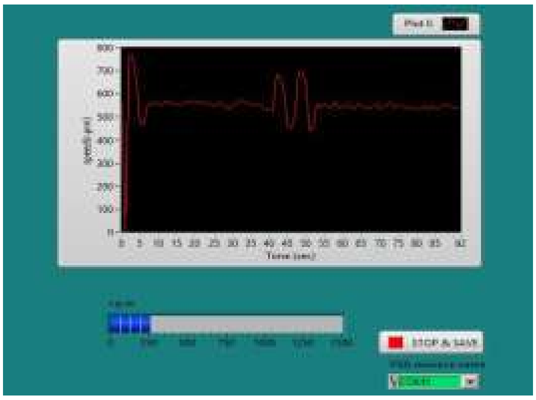

Figure 5: Pelton turbine speed response by using speed smart control system with changing the torque

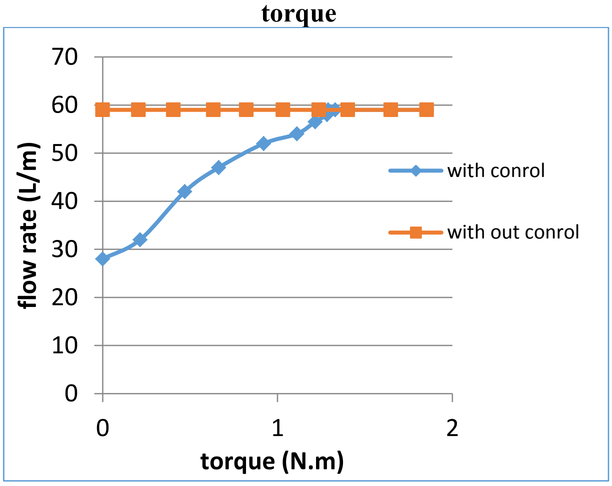

Figure 6: The relationship between the water flow rate and the torque of Pelton turbine with SSCS

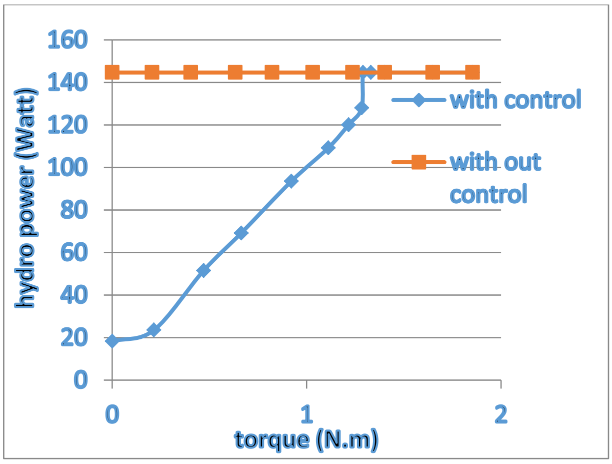

Figure 7: The relationship between the hydropower and the torque of Pelton turbinewith SSCS

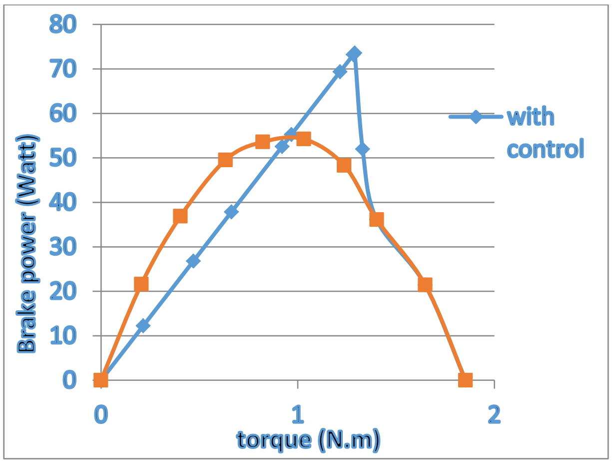

Figure8: Variation of brake power and torque of Pelton wheel with SSCS

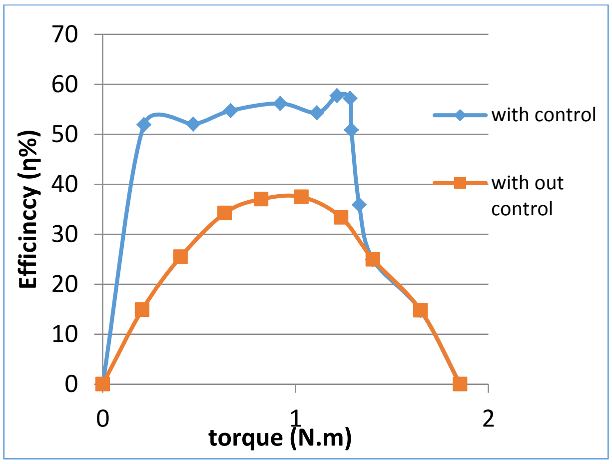

Figure 9: Variation of efficiency and the torque of Pelton turbine with SSCS

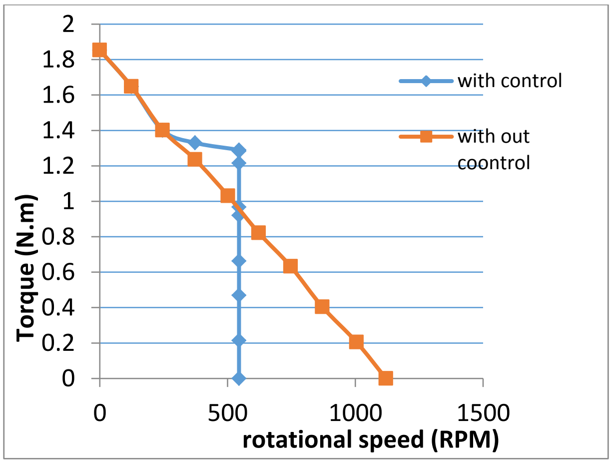

Figure 10: Variationof the torque and rotational speed of Pelton turbine with SSCS

Table 1: Performance of Pelton turbine with a speed smart control system

No of reading	Efficiency (η %)	Ph [N.m/s]	Pb [N.m/s]	Ω [rad/s]	T [N.m]	W2 [Kg]	W1 [Kg]	N mean (rpm)	D [mm]	Q [l/min]	H [mH2O]
1	0	18.321	0	57.0722	0	0	0	545	8.87	28	4
2	51.9355	23.544	12.22771	57.0722	0.21425	0.36	1.4	545	8.87	32	4.5
3	52.04	51.5025	26.806	57.0722	0.4697	0.62	2.9	545	8.87	42	7.5
4	54.74	69.16	37.858	57.0722	0.6633	0.78	4	545	8.87	47	9
5	56.18	93.522	52.555	57.0722	0.92086	1.13	5.6	545	8.87	52	11
6	49.33	112	55.2599	57.0722	0.9682	1.3	6	545	8.87	55	12.5
7	57.76	120.09	69.3689	57.0722	1.2154	1.6	7.5	545	8.87	56.5	13
8	57.19	128.02	73.223	57.0722	1.283	1.77	8	545	8.87	58	13.5
9	50.88	144.69	73.6	57.0722	1.29	2.5	8.8	545	8.87	59	15
10	35.91	144.69	51.96	39.07619	1.33	4	10.5	373	8.87	59	15
11	24.96	144.69	36.13043	25.77143	1.401	4.82	11.93	246	8.87	59	15
12	14.79	144.69	21.41393	12.99048	1.648	5.51	13.87	124	8.87	59	15
13	0	144.69	0	0	1.853	6.2	15.6	0	8.87	59	15

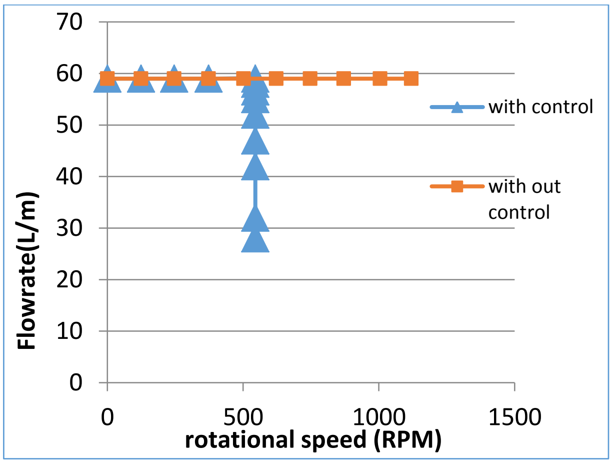

Figure 11: Variation of water flow rate and rotational speed of Pelton turbine with SSCS

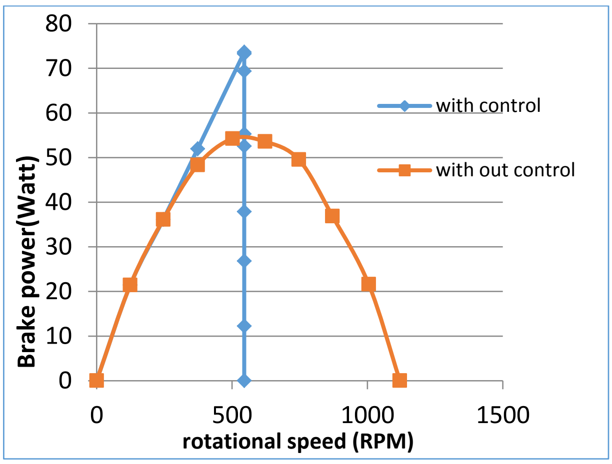

Figure 12: Variation of brake power and rotational speed of Pelton turbine with SSCS

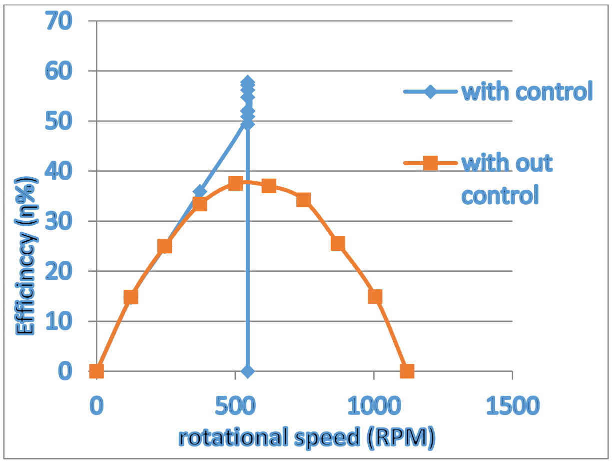

Figure 13: Variation of efficiency and rotational speed of Pelton turbine with SSCS

5. Conclusions

Based on the previous discussion of the obtained results, the following conclusion can be extracted.

1. The rotational speed time response about four seconds to achieve a steady state rotational speed of Pelton turbine.
2. It was observeda three regions (show in the figures) of performance characteristic for Pelton

turbine in the case of using Smart Speed Control System.

3. The use of Speed Smart Control System provides more stability to the Pelton turbine operation over wide range of water flow rate, so it makes the Pelton turbine work with high efficiency, power generated, and low amount of water consumed.
4. Using a Speed Smart Control System reduces a hydraulic power (input power) of the water according to the load applied to the shaft. The maximum reduction in the hydraulic power was approximately equate to 87.33% at zero torque.
5. The optimum torque for maximum brake power and efficiency of Pelton turbine system with smart speed control system is increased by 28.15%.
6. The Pelton turbine system performance with SSCS have been improved and enhanced. The percentage increase in the brake power and efficiency of Pelton turbine system were 26.3% and 35% respectively at the optimum torque for maximum brake power and efficiency of Pelton turbine system.

Nomenclature

Abbreviation	Meaning of Abbreviation	Abbreviation	Manning of Abbreviation
D	Nozzle diameter (m)	Q	Discharge (1/S)
F1	Load (N)	R	Brake wheel radius 0.021m
F2	Load (N)	SSCS	Speed smart control system
g	Acceleration m^2/S	t	Time (S)
H	Head of water m H_2O	T	Torque (N•m)
N	Revolution per minutes (rpm)	V	Volume of water
Ph	Input hydropower (W)	ω	Angular speed (rad/S)
Pb	Brake Power (W)	η	Efficiency
		ρ	Density of water (kg/m^3)

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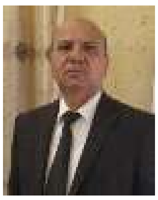

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