Controlling of Rotary Inverted Pendulum with Self-Tune Fuzzy PID

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Abstract: The inverted pendulum is widely used mechanism in designing of robotic arm. The aim of this research is to model a Self-tuned Fuzzy PID controller for inverted-pendulum; owing to that for proper modeling and controlling, LAB-VIEW is used to control real time parameters. The PID model is designed in Simulink and tested on inverted pendulum in real time. This self-tuned PID works on error and is sent to computer-based model to generate suitable output for pendulum. The microcontroller-based interface is used to get input from rotational inverted pendulum; as per difference in error movement is updated via feedback signal of sensor until the stable position is achieved. The parameters of PID are set by self-tuning algorithm. The research is very helpful for implementing the concept in self-stabilizing robots.

Keywords: *Inverted pendulum, PID control, Self-tuned fuzzy controller, Lab-View, Stability.*

1. Introduction

Inverted pendulum is 2D oscillating rotational inverted pendulum with two independent motions (DOF- Degrees Of Freedoms). Robotic inverted pendulum's angle along forward and reverse way is a mainstream show of utilizing input control to settle an open-circle insecure framework. The primary arrangement maybe to this issue was depicted [1].

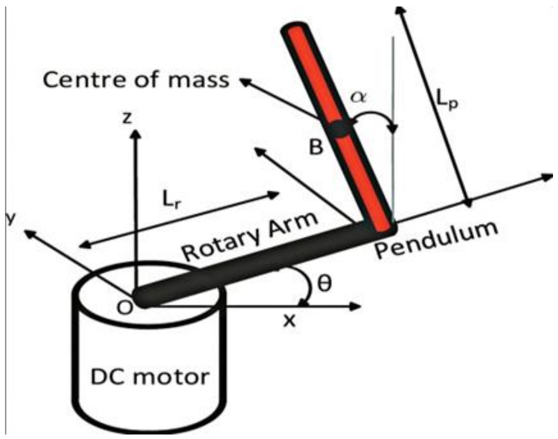

Figure.1. Block Diagram of Inverted Pendulum [1]

Thusly, as per evaluation done by numerous analysts [2] a typical criterion control for the examination of programmed control strategies, linearizing strategies are utilized at large portion for control design. Due to non-linear behavior of model the research work broadly utilizes control techniques for hypothesis to confirm cutting angle; accordingly, the concept is valuable for outlining a portion of the thoughts in controlling nonlinear workspace. The narrow standing pole of the pendulum with pivoted base, alluded to as rotate point, mounted on a heading. The conditional diversion of the pendulum's heading angle α Arm θ, moves on a level plane with a specific end goal to convey the pendulum to stable a Proportional-Derivative PD fuzzy controller is utilized to balance the pendulum to equilibrium state. The zero-reference point of pendulums pole is connected to one of main encoder i.e. potentiometer (pot) of the model; accordingly, due to varying positions different voltages are produced that are compared to zero reference point voltage thus a proper control signal is generated.

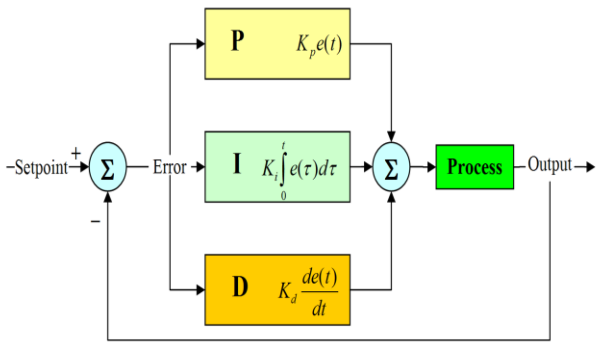

Figure.2. Block diagram of PID controller.

The calculation of model was set up to reproduced by using PROTIUS programming and Lab-view Simulink has been utilized for testing and recreation of positions with various estimations of proportional gain (*Kp*) and differential gain (*Kd*) to produce current reactions of prototype. Fuzzy logic depends on four essential ideas: fuzzy sets, phonetic factors, probability conveyances, and fuzzy if-then principles. Fuzzy sets will be sets with un sharp limits.

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Etymological factors are factors whose qualities are characterized by a fuzzy set. Probability conveyances are imperatives on the estimation of a semantic variable set up by doling out it a fuzzy set.

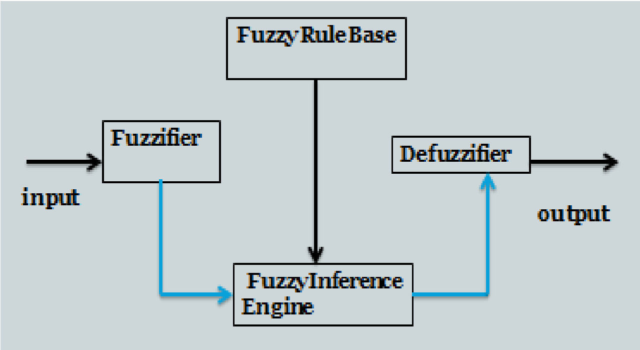

Figure.3.Black diagram of fuzzy logic

Fuzzy if-then decides are decides that sum up a suggestion in two-esteemed logic. Fuzzy sets enable fractional membership to different sets, not at all like traditional sets where components have a place with just a single set or the other. In fuzzy sets, membership involves degree; the degree is indicated by a number somewhere in the range of 0 and 1[6].and the inverted pendulum working as Newton's Third law of motion.

1.1 Potential Energy: (P.E)

$\boldsymbol{y_p}$ is used to find the potential energy, u_t

$$U_t(\alpha) = M_p\ gL_p(1 - \cos(\alpha(t))\ ) \qquad (1)$$

Pendulum position at down word position,

$\alpha = 0$, $u_t(\alpha = 0) = 0$J Pendulum is at the upright position, $\alpha = \pi$, Ut $(\alpha = \pi) =$ Mp g Lp (2)

1.2 kinetic Energy: (K.E)

T_t is used for pendulum rotation.

$$T_t = \frac{1}{2} J_p\ (\alpha)2 \qquad (3)$$

1.3 Pendulums inertia movement:

To find out inertia frequency of pendulum. when swing freely so,

$$T_p = 0, \quad \alpha = 0 \qquad (4)$$

The set-up equation is non-liner, to linearize the equation sin $(\alpha) = \ \alpha$ when the small value of α.

$$J_p\ (\alpha) + M_p\ g\ L_p\ \alpha = 0 \qquad (5)$$

To solve the linearized equation, use the following initial condition.

$$\alpha\ (0) = \alpha_0 \qquad (6)$$

then, the Laplace transform of the linearized equation:

$$J_p\ (S^2\alpha(S)\text{-}\alpha_0)\text{+}M_g gL_p\alpha(S) = 0 \qquad (7)$$

$$\alpha(S) = \frac{\alpha_0}{S + \frac{M_p\ g.\ L_p}{J_p}}$$

Therefore, the frequency f

$$\frac{\sqrt{\frac{Mp\ g\ L_p}{J_p}}}{2\Omega} \qquad (8)$$

2. Methodology

Main QNET Rotary pendulum features and the parameters involved in this research work are given in Table 1:

- Condensed and full rotational servo system for NI ELVISII(+)
- 18-Volt direct drive brushed DC motor.
- 12-volt encoder scale for Direct Current (DC) motor and pendulum.
- Built-in Pulse Width Modulation (PWM) amplifier.
- Built-in Peripheral Component Interface (PCI) connector for NI ELVISII (+).

2.1 DC motor: The QNET Rotary pendulum incorporates an immediate drive 18 V brushed 12-volt DC motor attached in strong aluminum outline, motor determination, QNET Rotary pendulum consolidates an Allied movement CL40 arrangement core less dc motor model 16705.

2.2 Encoders: The encoders are attached for position of dc motor and pendulum of QNET Rotary pendulum is single-finished optical shaft encoders. They yield 2048 include per insurgency quadrature mode 512 lines for every revolution. the encoders are quantifying the precise position of motor and pendulum of the QNET Rotary inverted pendulum is Digital (E8P-512-118) single-finished optical shaft encoder.

2.3 power amplifier: QNET Rotary pendulum circuit board incorporates a PWM voltage-controlled power amplifier skilled to giving 2A top current and 0.5A ceaseless current (dependent on the warm current rating of the motor) the yield voltage range to the heap id between 10V.

Table 1. Rotary Inverted Pendulum specification.

Symbol	Description	Value
	DC Motor	
Vnom	NOMINAL VOLTAGE	18.1 V
Tnom	NOMINAL TORQUE	22.1 mnm
Wnom	NOMINAL SPEED	3051 rpm
Inom	NOMINAL SPEED	0.541 a
Rm	TERMINAL RESISTANCE	8.40
Kt	TORQUE CONSTANT	0.043 nm/a
Km	MOTOR BACK EMF	0.043 v/(rad/s)
Jm	ROTO INERTIA	4.1×10^{-6} kgm2
Lm	ROTORINDUCTANCE	1.17mh
Mh	MODULE ATTACHEMENT HUB MASS	0.017 kg
Rh	. MODULE ATTACHEMENT HUB RADIOUS	0.0112 m
Jh	. MODULE ATTACHEMENT MONENT	0.7×10^{-6} kgm2
	Rotary Pendulum Module	
M_r	ARM MASS	0.096 kg
L_r	ARM LENGTH	0.086 m
M_p	PENDULUM LINK MASS	0.023 kg
L_p	PENDULUM LINK LENGTH	0.128 m
	Motor and Pendulum Encoders	
	ENCODER LINE COUNT	512 lines/rev
	ENCODER LINE COUNT IN QUADRATURE	2048 lines/rev
	ENCODER RESOLUTION QUADRATURE	0.177 deg /count
	Amplifiers	
	AMPLIFIER TYPE	Pulse Width Mod
	PEAK CURRENT	2.56
	CONTINUOUS CURRENT	0.56
	OUTPUT VOLTAGE	±24v to (±10v)

After the structure is exhibited the controller can be arranged. In any case. The swing-up controller registers the torque that will be associated with a pendulum base arm. with the objective that the inverted pendulum will be turned up word. When the pendulum is swing-up to a particular range about its upright vertical angle using the swing-up controller, the balance controller expect control to balance the pendulum in figure.12

A fuzzy PD type controller proposed to modifying the pendulum system as showed up in Figure.4

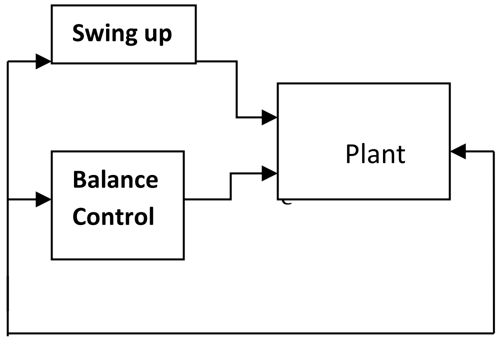

Figure.4. Black diagram of Swing up controller

Rotary pendulum system shown in figure 5, which shows the complete pendulum system in block diagrams.

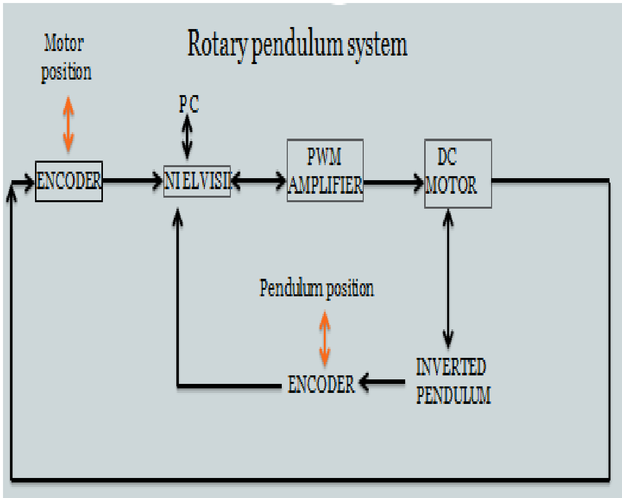

Figure.5. Rotary pendulum System [5]

It yields the controller for relative gain of the inverted pendulum angle, fuzzy controller objective to altering low pass ability for dc motor, where inverted pendulum on certain angle, pendulum exact speed is at certain angle, independently , so the gain will be extended. In case the angle is sure and daring pace is negative, or the fact of the matter is negative and the exact speed is certain, angle. the gain will be more.

3. Results and Discussion

Toward the true objective to test the controller assign the QNET 2.0 Rotary pendulum was used with National Instruments' Lab-VIEW as the programming condition, Introductory, an affiliation is developed between the PC and the QNET 2.0-Rotary pendulum in Lab-VIEW, showed up. in the wake of making an association the following assignment is to peruse from the sensors on the QNET 2.0 rotary pendulum; this progression is appeared in figure.6.

Figure.6. Rotary Inverted pendulum kit

After acquiring the sensor information, that information is utilized to make the framework states, and demonstrate the Lab-VIEW code for making the framework states figure.10

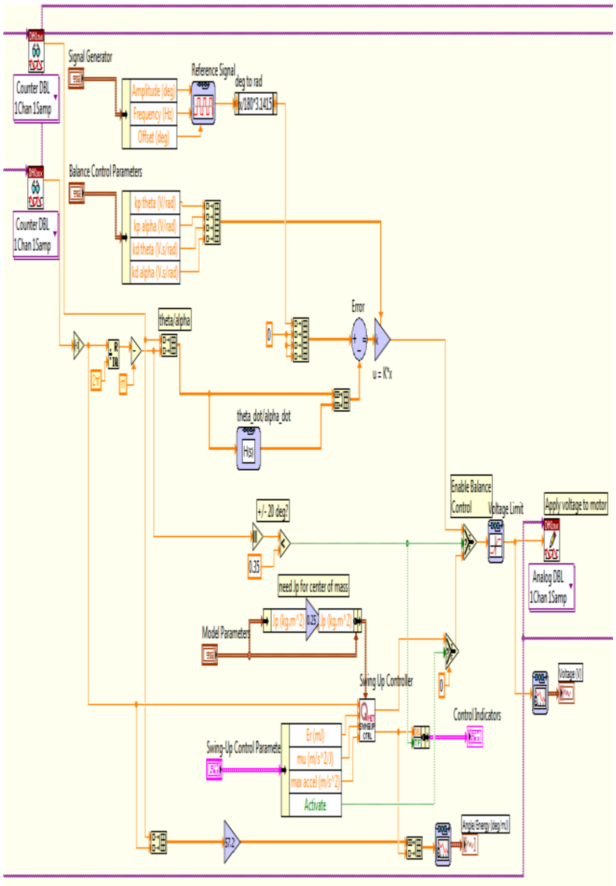

Figure.7. PD Controller in Lab-view

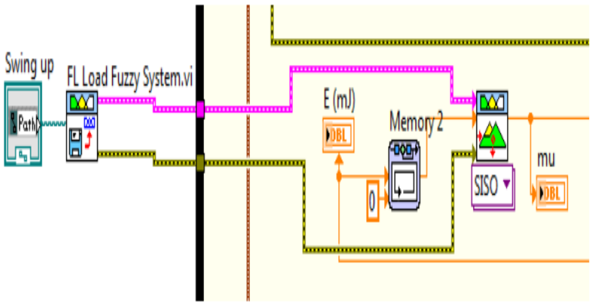

Figure.8. Swing up control in Lab-View

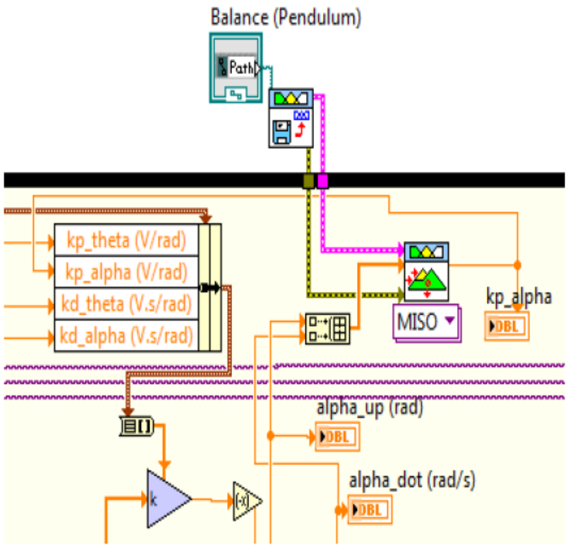

Figure.9.Balance control in Lab-view

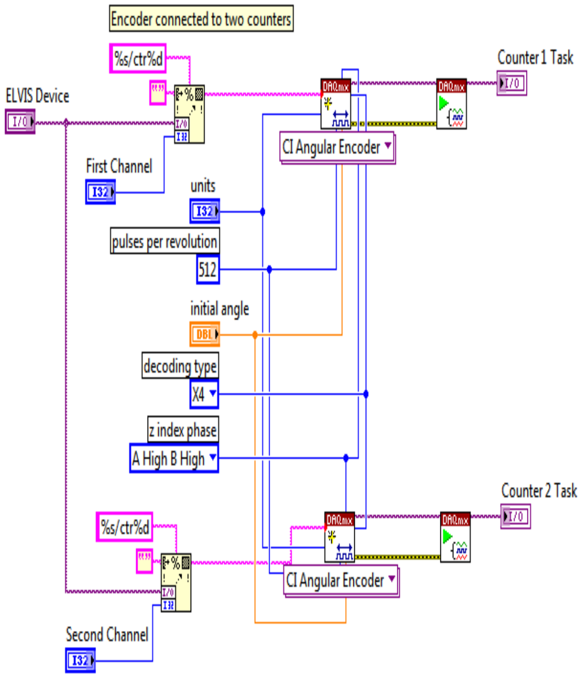

Figure.10.Ecoders in Lab-view

Next making joining, the next task is to read from sensor data.that data used to form the sytem state α - $\dot{\alpha}$ - θ - $\dot{\theta}$. The values of the sysytem state are then used to controller switch which deermine the balabce control should be acitve.

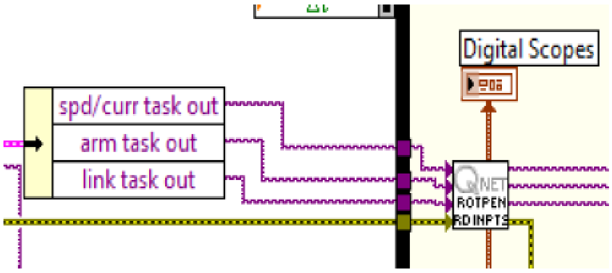

Figure.11. Reading sensor data in Lab-view

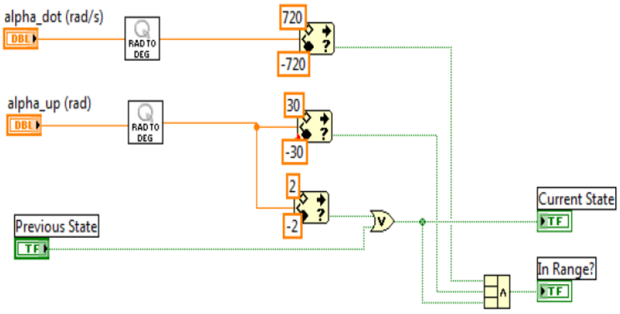

Figure.12. Lab-view code for control switch.

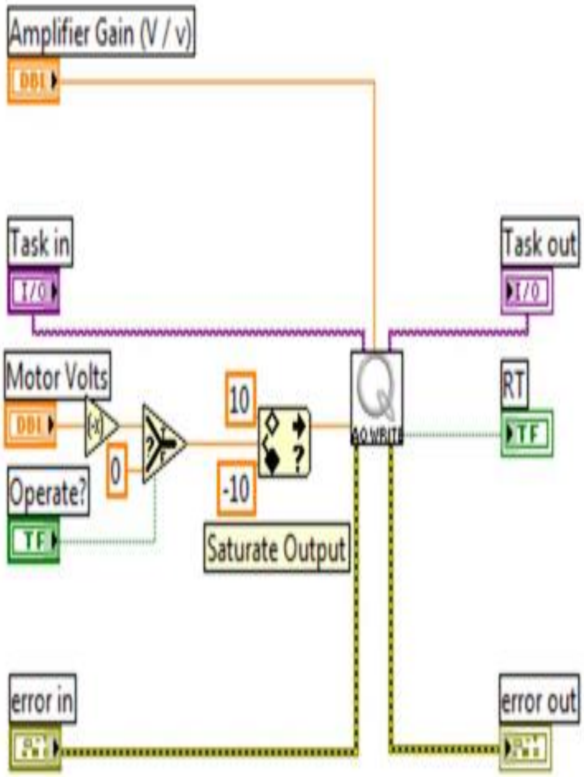

Figure.13.Amplifier Gain in Lab-View

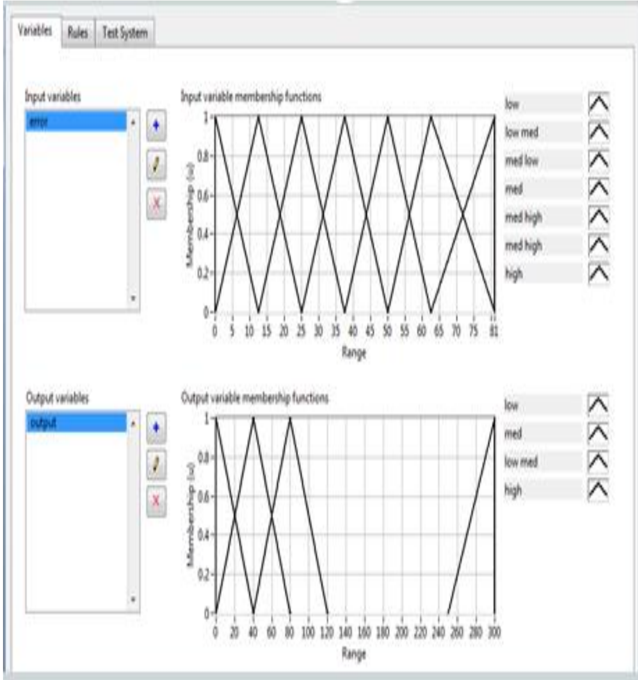

Figure.14.Fuzzy output

(1.)	If	is 'Z' and is 'Z', then		is 'High'.
(2.)	If	is 'Neg' and	is 'Z', then	is 'Med'.
(3.)	If	is 'Neg' and	is 'Pos', then	is 'High'.
(4.)	If	is 'Neg' and	is 'Neg', then	is 'Low'.
(5.)	If	is 'SlightNeg' and	is 'Z', then	is 'Med'.
(6.)	If	is 'SlightNeg' and	is 'Pos', then	is 'High'.
(7.)	If	is 'SlightNeg' and	is 'Neg', then	is 'Med'.
(8.)	If	is 'SlightPos' and	is 'Z', then	is 'Med'.
(9.)	If	is 'SlightPos' and	is 'Pos', then	is 'Med'.
(10.)	If	is 'SlightPos' and	is 'Neg', then	is 'High'.
(11.)	If	is 'Pos' and	is 'Z', then	is 'Med'.
(12.)	If	is 'Pos' and	is 'Pos', then	is 'Low'.
(13.)	If	is 'Pos' and	is 'Neg', then	is 'High'.

Figure.15. Fuzzy Rules.

appears inside the subsystem in and demonstrates that and are made by going them result of distinguish. The estimations of the framework states are then utilized in the control switch, made reference to in section, and it decides whether the adjusting controller ought to be enacted. The Lab-VIEW code succession is appeared in Figure 10. The control switch is the QNET 2.0 Rotary pendulum Balance control.

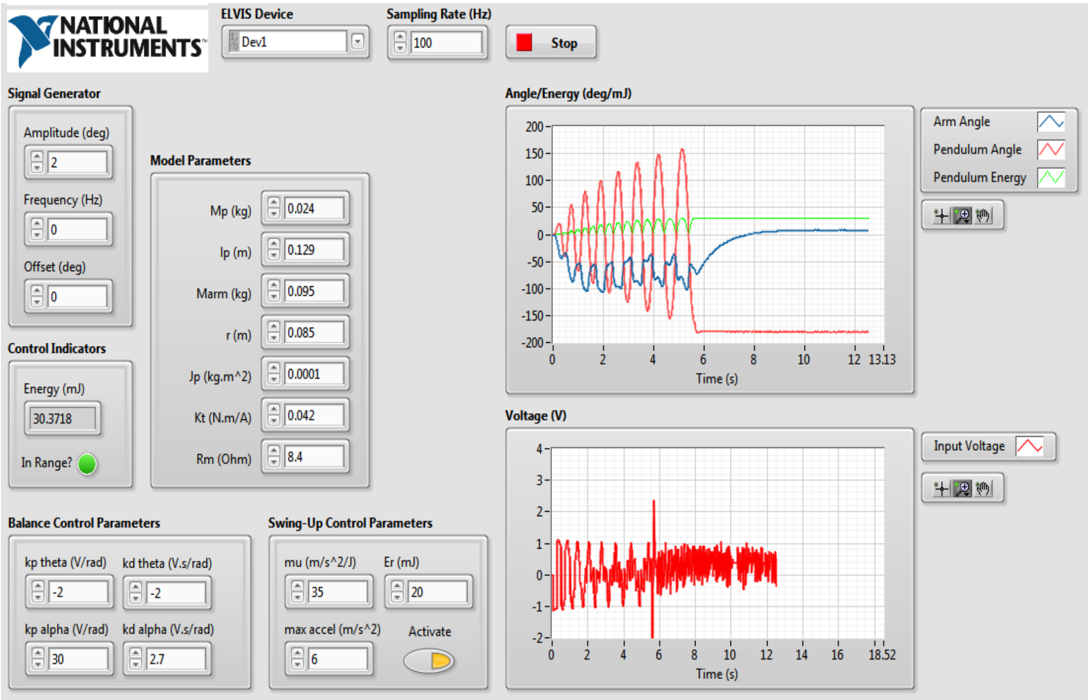

Figure.16. Lab-view output

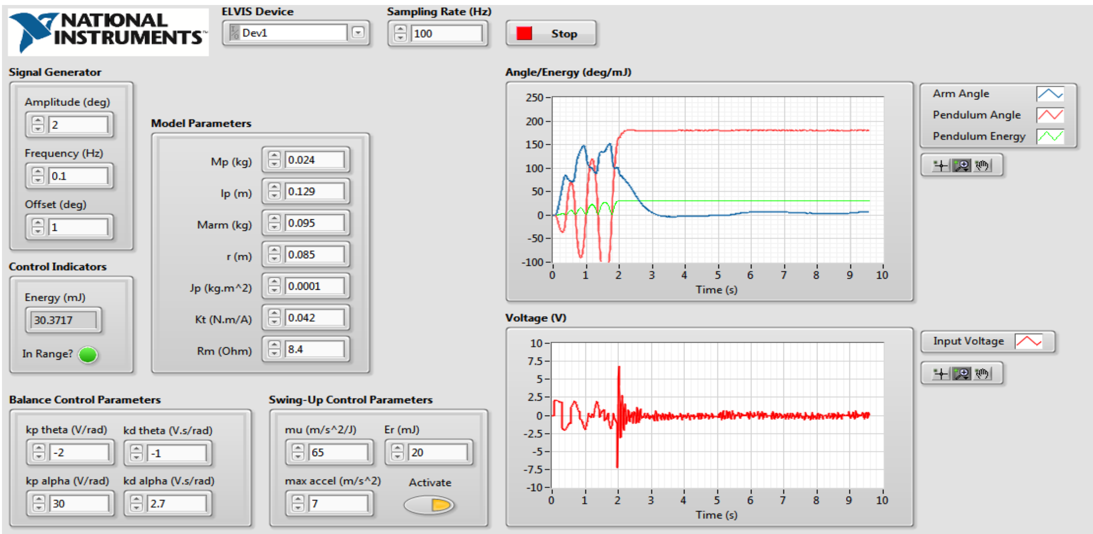

Figure.17. Lab-view output

4. Conclusion

The inspiration driving this endeavor was to make a PD Fuzzy controller for the QNET 2.0 Rotary pendulum QNET 2.0 Rotary pendulum of the Quanser Engineering supplanting the primary PD controller arrangement obtainable for the DC motor. The PD Fuzzy system is made by exchange the encoding relating term in the standard PD controller with fluctuating terms reliant on feathery method of reasoning structure and differentiated and PD type controller. Various analysis was continued running for the PD Fuzzy type controller.

PD Fuzzy type controller exhibited to has a fast organize time, and a more diminutive persevering state bumble than the PD type controller, The pendulum's12-volt DC motor moreover systematization capacity on some speed PD Fuzzy type controller. As an end, the arrangement of the PD Fuzzy controller displayed in this description is viable, and execute favored in difficult over the standard PD type controller in changing an rotary inverted pendulum.

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References

[1] T.K. Chey and T.C.San. Rotary "Inverted Pendulum BS Project" Nanyang Technology University, 1999. Web 20. Feb,2017.

[2] N.S. Nise. Control system engineering 6th edition. Johan Wiley & Sons, Inc.2011.

[3] C. Dey and R. K. Mudi, " An adaptive PD type flc with its real-time implementation on a servo position control system," Proc. IEEE international conference on Fuzzy system-Fuzz-IEEE,pp.1-7,2013

[4] Quanser.Qnet practical control guide 2016

[5] Quanser.Qnet inverted pendulum control laboratory manual 2016

[6] [Chin-wen chuange, "The self-tuning PID Control in a toggle mechanism system by knowledge based bounds," In control , Automation and Robotics (ICCAP) 2016 PP 118-212 IEEE, 2015.

[7] Kasruddin , A. N., Modeling and Controller Design for an Inverted Pendulum System, Master Thesis, Faculty of Electrical Engineering, Universiti Teknologi Malaysia.

[8] Jain, T. and Nigam, M. J., Optimization of Pd-Pi Controller Using Swarm Intelligence, 2008, Journal Of Theoretical And Applied Information Technology.

[9] Astrom, K. J. and Furuta, K., 2000, Swinging up a Pendulum by Energy Control, Automatica.

[10] N.S. Nise. Control systems engineering 6th edition. John Wiley & Sons, Inc. 2011

[11] K. Ogata. Modern control engineering 5th edition. Pearson Prentice Hall, 2010.

[12] J. Yen and R. Langari. Fuzzy logic: Intelligence, control and information. Pearson Education, Inc, 1999.

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