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RESEARCH ARTICLE

Solar-Wind Hybrid Energy System with PID Controlled Water Pump.

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Abstract

The aim of the work is to present a PID controlled water pump run by a solar-wind hybrid energy system which is controlled by a LTC3784 controller. The hybrid system consists of a Photovoltaic (PV) array, a wind turbine, a Permanent Magnet Synchronous Machine (PMSM), a three phase diode bridge rectifier, a LTC3784 controller, a PID controller and a water pump. The main objective of the paper is to show that a water pump can be powered up by either a solar or a wind energy system with a constant voltage of 24V which is controlled by LTC3784 controller. The water pump is controlled by a PID controller. The proposed model of the hybrid system is mathematically designed and simulated by using PSIM and LTspice software and the model of PID controlled water pump is designed and simulated in MATLAB/Simulink. The simulation results show that the whole system can be implemented into hardware.

Introduction:-

Hybrid system is being employed in the world in recent years. They are more reliable than using only one renewable energy source though it is costly but long lasting as well. With the world energy demand increasing at an exponential rate, the search for energy sources other than fossil fuels is no longer a luxury. Although the fossil fuels offer a temporary solution to this energy crisis, they cause the emission of carbon dioxide and other greenhouse gases, which are harmful to the environment. Hence scarcity of fossil fuel resources and environmental effects, Bangladesh's energy strategy attempts to raise the reliance on renewable energy resources, primarily in photovoltaic and wind concentrated power [1].

In remote areas, there is deficiency of electricity and people face problem in collecting water as they lack resources and usually have to travel far to collect water. To solve all these problems, a proposed system has been presented in this paper where a hybrid system can be used as a power source for the water pump. The pumped water can be used in many applications such as domestic use, water for irrigation and village water supplies [2]. The initial cost is high but it is actually worth it because it will work in a long term process providing sustainable energy in the form of electricity.

Using photovoltaic as the power source for water pumping is considered as one of the most promising areas of PV application [2]. Despite of the conventional way of water pumping the proposed model presents a new and more reliable way of pumping water. The proposed system will work day and night regardless of other necessities because if there is no sunlight, the wind system will work and vice versa. Both the modules can even work together to compensate for each other. The advantages of using water pumps powered by the hybrid system include low maintenance, ease of installation, reliability and effortless water collection.

Most of the control performances in the actual design are usually defined by overshoots, rising time, settling time, steady state error etc. [3, 4 and 6]. Proportional-Integral-Derivative (PID) controller is reliable and accurate.

Furthermore, they are used in industrial feedback control loops, PID controller can be used to control the complex system to get the better performance [5, 6]. It is also the most adopted controller in the industry due to the good cost and given benefits it poses to the industry [7, 8]**.**That is why the controller which has been used for pumping water in this proposed system is a PID controller.

Any model is first designed keeping ideal conditions in mind and if it functions properly, then the task is to deal with situations such as the hybrid system not functioning or the hybrid system lacking natural energy needed to drive the system. In this paper, Solar-Wind hybrid system is connected in parallel connection so that both can work simultaneously and individually. Then the output is transferred to the controller LTC3784. The controlled constant voltage is then fed to the water pump as the power source. All the parameters of the elements are mathematically derived and the designed values are simulated in PSIM, LTspice software and Simulink to analyze and verify our proposed model. The block diagram of the proposed system is shown below in Fig.1.

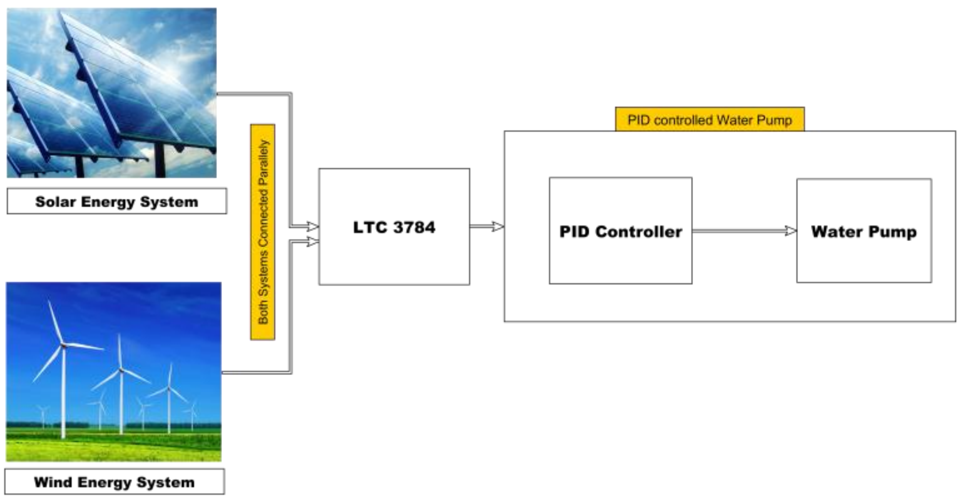


Fig.1. Block diagram of the proposed system

Design of solar-wind hybrid system

A. **Solar System:-**

The solar panel used here is Resun Solar Energy’s solar panel [9], under Standard Test Condition (STC), with 240W maximum output power. At STC condition of 25º temperatures, and irradiance of 1000 W/m, the panel is simulated to give an output of 24V. The design parameters of the solar system are listed in Table I and the output is shown in Fig.2.

Table1. Design parameters of Solar System

Parameter	**Value**
Number of cells	60
Standard Light Intensity,S_0	1000W/m^2
Reference Temperature, T_{ref}	25^0C
Series Resistance, R_s	.0155Ω
Shunt Resistance, R_{sh}	1000Ω
Short Circuit Current, I_{sc}	9.09A
Temperature Coefficient, Ct	.005454

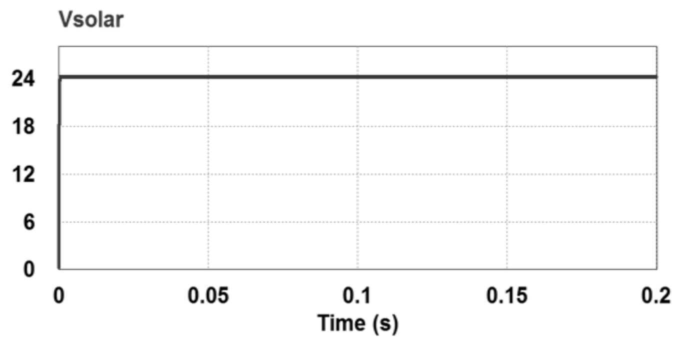


Fig.2. Simulated Output of the Solar System

B. **Wind System:-**

In this paper, the system parameters of a 230W Wenzhou SUG New Energy Co., Ltd'sSNE-200S [10] wind turbine have been considered for design and simulation. The wind turbine is connected to the gear box and the electrical-mechanical interface and then to permanent magnet synchronous generator to produce an AC output. The parameters are listed in Table II and III. The system gives 24V output which is shown in Fig.3.

Table 2. Design parameters of Wind Turbine

Parameter	**Value**
Nominal Output Power	230W
Base Wind Speed	10 m/s
Base Rotational Speed	10m/s
Initial Rotational Speed	0.8
Moment of Inertia	1m kg.m^2
Short Circuit Current, I_{sc}	9.09A
Gear ratio	4.28

Table 3. Design parameters of PMSM

Parameter	**Value**
Stator Resistance, R_s	1mΩ
D-axis inductance	1mH
Q-axis inductance	1mH
V_{pk}/krpm	4000
No. of poles	4
Moment of Inertia	100m kg.m^2

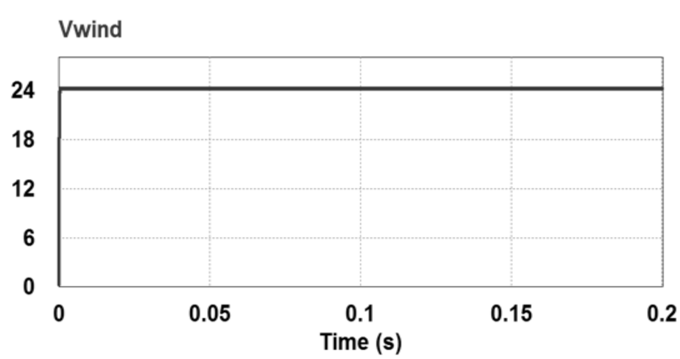


Fig.3. Simulated Output of the Wind System

C. **Combined Solar-Wind System:-**

There are two ways by which the hybrid system can be used. Two outputs coming from solar and wind system can be added together and both can produce power simultaneously so that if one source is not available, the other one can compensate for it. The system can be handled manually too. The solar system can work in day time and the wind energy system can work at night. In our proposed system, it is suggested to use the hybrid system manually as it will save a lot of power otherwise a lot power will be wasted. The designed model is shown in Fig.4.

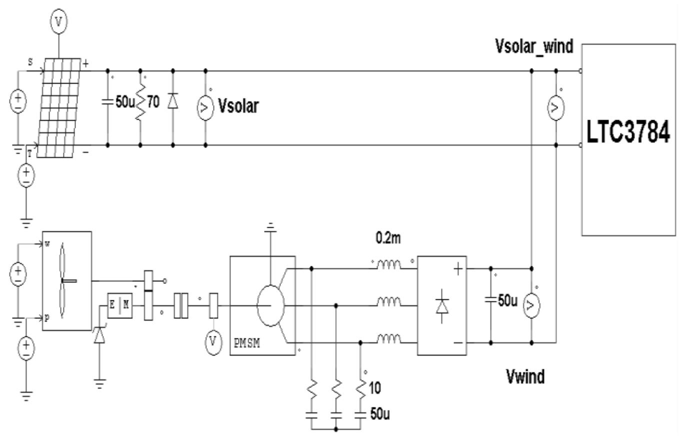


Fig.4.Combined Design of Solar & Wind System

Controller LTC3784:-

The output from both solar and wind system is uncertain. One might produce more power and other might produce less. The worst case scenario would be if either system produced little or no power at all. Keeping such cases in mind, it has become essential to control the voltage output of this hybrid system. To get a constant voltage from the system, LTC3784 IC has been used. This IC can take input from 4.5V DC to 60V DC. But to give a fixed output of 24V DC, the input needs to be between 7V DC to 24V DC. It is a product of Linear Technology [11]. The output power of LTC3784 is 240W at 10A. The configuration of LTC3784 is shown below in Fig.5.

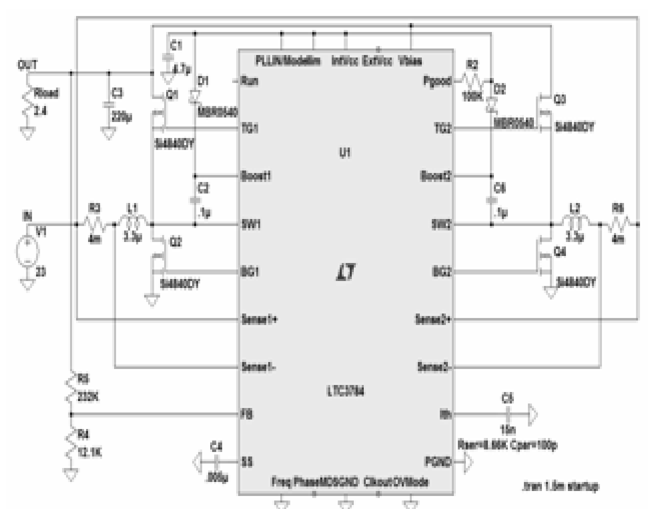
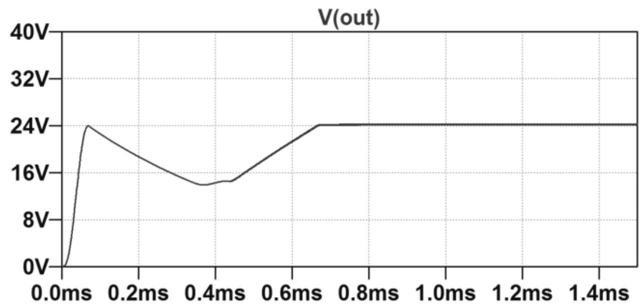


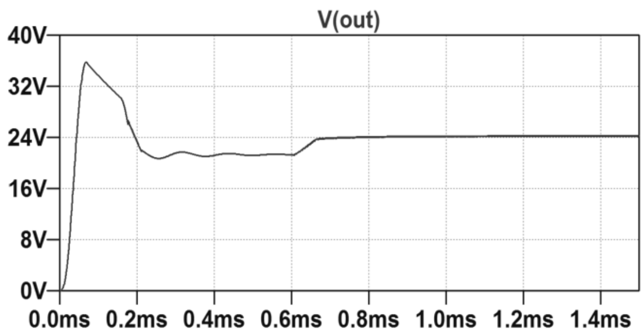
Fig.5. Configuration of LTC3784

The simulation has been done with LTspice IV, which is a product of Linear Technology. The IC LTC3784 gives 24V DC output whatever is the input between 7V and 24V. The proposed model is simulated for 10V, 20V and 24V.

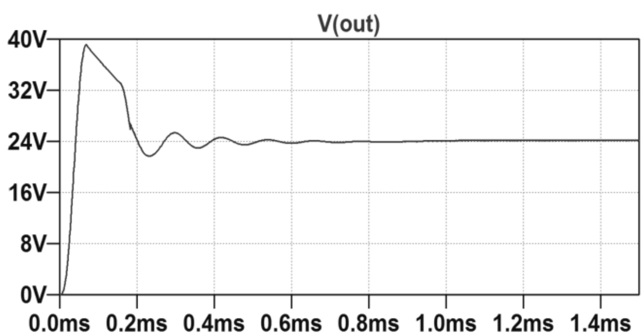
From the simulation it can be seen that the output voltages of LTC3784 are constant at 24V as shown in Fig.6 (a), (b) and (c). The current also remains the same for all the voltages (7V-24V) which is 10A and that is shown in Fig.7 (a), (b) and (c). The output power for 10V, 20V and 24V input voltages are shown in Fig.8 (a), (b) and (c). These graphs show that the output power remains constant at 240W for different input voltages confirming the proposed system as reliable and stable. Thus, regardless of the conditions, the water pump will get a fixed input of 24V as power supply.



(a)

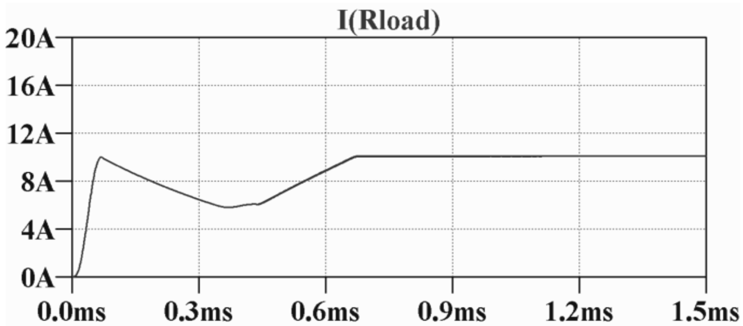


(b)

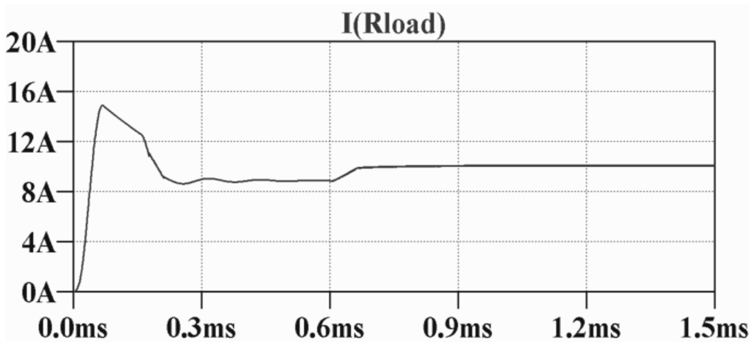


(c)

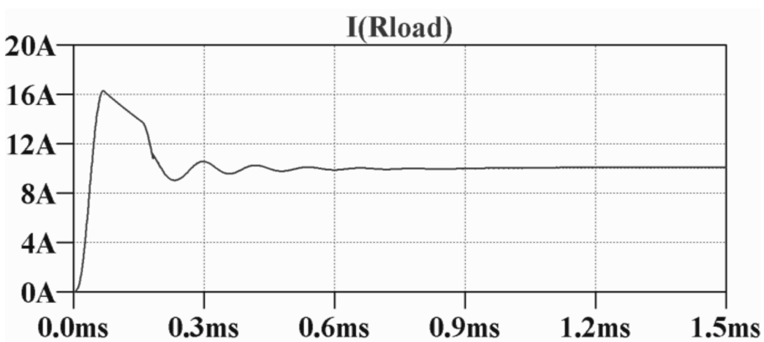
Fig.6.Simulated Output when input is (a) 10V (b) 20V and (c) 24V



(a)

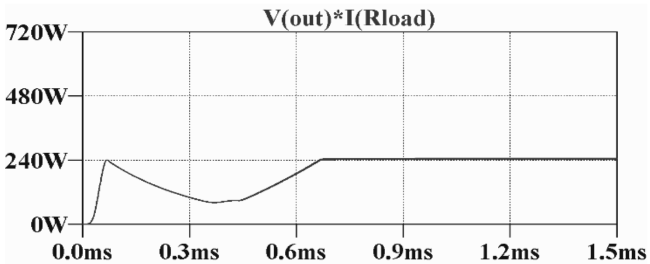


(b)

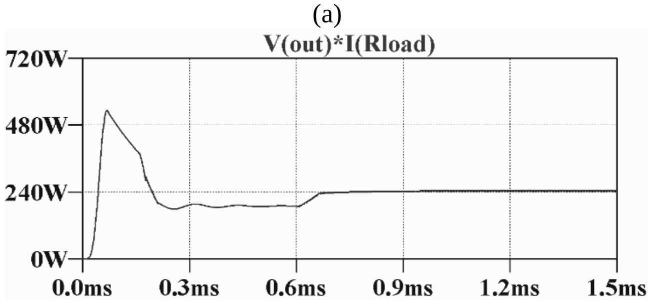


(c)

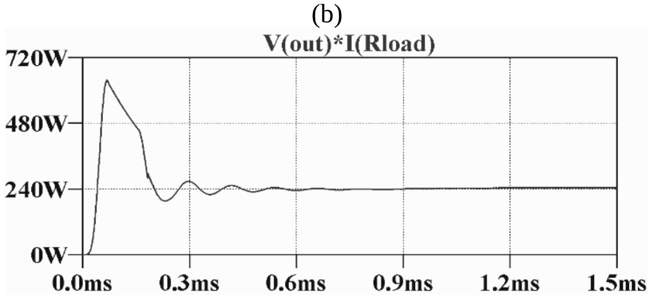
Fig.7.Simulated Output Current when Input is (a) 10V (b) 20V and (c) 24V



(a)



(b)



(c)

Fig.8.Simulated Output Power when Input is (a) 10V (b) 20V and (c) 24V

PID Controller:-

A controller is designed to control the overall the system. The block diagram of a feedback control system is shown below in Fig.9.

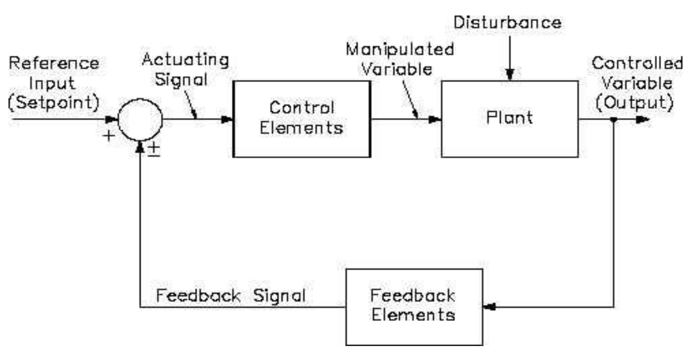


Fig.9. Block diagram of a feedback control system

The PID controller is the most common form of feedback. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable. The Proportional value determines the reaction to the current error, the Integral value determines the reaction based on the sum of recent errors, and the Derivative value determines the reaction based on the rate at which the error has been changing.

The transfer function of PID controller looks like the following:

$$K_p + \frac{K_I}{s} + K_d s = \frac{K_d s^2 + K_p s + K_I}{s}$$

Here, K_p = Proportional gain

K_I = Integral gain

K_d = Derivative gain

Let's assume the above diagram of a controller is a PID controller. R is the input, e is the error, u is the signal after the controller is computed, and Y is the output. First the input is given to the controller and then it goes to the plant to output. Till the output is not almost equal to the input, the output is fed back to the input. And the error goes to the controller where u is the sum of K_p is multiplied with e, K_I is multiplied with the integral of e and K_d is multiplied with the derivative of e. Thus the error is eliminated.

$$u(t) = K_p e + K_I \int edt + K_d \frac{de}{dt}$$

The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variable (MV).

$$MV\ (t) = P_{out} + I_{out} + D_{out}$$

Where,

Pout, I_{out}, and D_{out} are the contributions to the output from the PID controller from each of the three terms, as defined below in Fig.10.

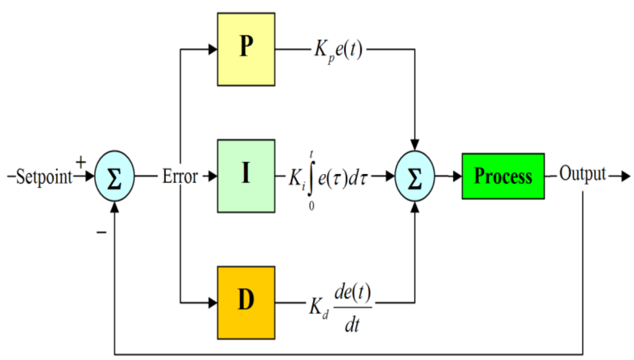


Fig.10. Block Diagram of PID controller

Water Pump with PID Controller:-

The dc voltage coming from the controller is fed to the PID controlled water pump. The pump works at 24V. As the initial input voltage coming from the solar and wind energy system can be anything between 7V to 24V which is controlled by LTC3784 to get a constant dc voltage of 24V, the water pump will eventually start working in all conditions. The water pump is controlled by a PID controller as it stables the pump output and gives almost an accurate result which is not possible without a PID controller. The diagram of a PID controlled water pump is shown below in Fig.11 which is designed in Simulink.

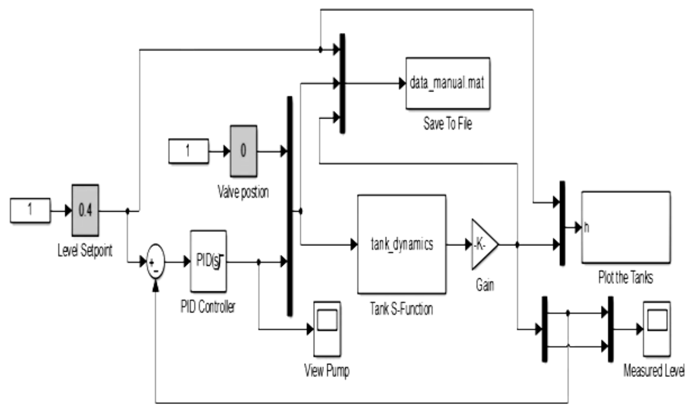


Fig.11. Process Model with PID Controller

The output coming from the water pump is set to a level of 0.4 to check whether it gives the correct output or not. The set point level can be changed according to the needs of the user from 0 to 1. With the level of 0.4, the output from the pump is seen in Fig.12.

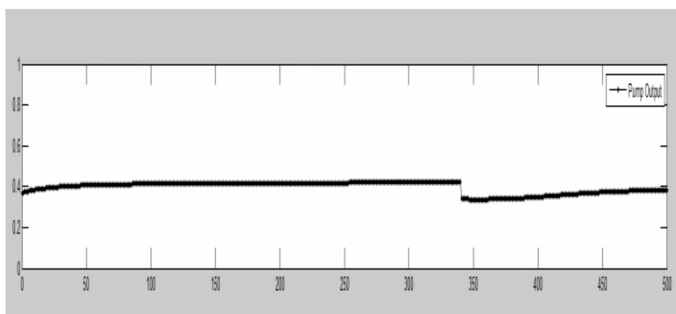


Fig.12. System Output with PID controller

It can be seen from the above graph that the pump output is almost as the set point. The pump output does not fluctuate much within 0.4. Even if the output comes a little under 0.4, it starts to increase and goes up at 0.4. The output graph of the pump shows the stability behavior of PID controller. If it starts to rise over than 0.4 the system stabilizes to 0.4 and vice versa. This is the reason for using the PID controller in pumping water as it automatically stabilizes and gives the desired output.

Future Work:-

The entire proposed system has been simulated and the results are quite satisfactory. The system is mainly designed for an ideal situation so the future work will deal with situations regarding functionality of the system if natural energy sources are not present or are present at a very scarce margin. The entire schematic has been only implemented in software but as the result is good enough and acceptable, it can be implemented in hardware too. If the proposed system can be turned into a full hardware system, it can be implemented in remote areas where water necessities are at large. The system will be beneficial both economically and socially and it will bring a drastic change in the next few years in the remote areas of Bangladesh. It should also be noted that pollution is kept at a minimum as the system uses natural sources of energy to produce the desired results hence making it environmental friendly.

Conclusion:-

In this paper a PID controlled water pump powered up by a hybrid solar-wind system has been presented. Along with this, the whole proposed system has been discussed and presented with mathematical modeling, analysis and computer simulation. Any voltage coming from solar and wind energy can be controlled with LTC3784 and as it gives a constant voltage, it has been used as a power source of a PID controlled water pump. It can be said that the simulation results prove that the proposed PID controlled water pump using solar-wind hybrid energy system with controller LTC3784 can be used in any remote area to give a reliable and sustainable water supply source.

References:-

1. S. Chakraborty, M. A. Razzak, "Design of a transformer-less grid-tie inverter using dual-stage buck & boost converters", International Journal Of Renewable Energy Research, Vol.4, No.1, pp. 91-98, March 2014.
2. K. B. Rohit, Prof. G. M. Karve, Prof. Khatri, "Solar Water Pumping System", International Journal of Emerging Technology and Advanced Engineering, Vol. 3, Issue 7, pp. 323-337, July 2013.
3. Bequette, B. W.2003, "Process Control Modelling, Design and Simulation", Prentice Hall.
4. Sudheer, L. Shrimanth .2013, " step variation studies of ARM7 microcontroller based Fuzzy logic controller for water-in-tank level control", (IJEET), Vol.4, pp. 405-415
5. Smith, C. A and Corripio .2006, A. B, "Principles and Practice of Automatic Process Control", 3rd ed., John Wiley & Sons, Inc.
6. L. A. Sabri, H. A. Al-Mshat, "Implementation of Fuzzy and PID Controller to Water Level System using LabView", International Journal of Computer Applications, Vol.116, No. 11, April 2015.
7. Aurelio Piazzi and Antonio Visioli, A Non causal Approach for PID control, Journal of Process Control, 4 March 2006.
8. M. M. Noh, M. S. Najib, N. S. Abdullah, "Simulator of Water Tank Level Control System Using PID-Controller", 3rd IASME / WSEAS Int. Conf. on WATER RESOURCES, HYDRAULICS & HYDROLOGY (WHH '08), University of Cambridge, UK, Feb. 23-25, 2008
9. http://www.alibaba.com/product-detail/240W-24V-Poly-Solar-Panel with_1176369097.html?spm=a2700.7724857.35.1.owruKK accessed on 21 August, 2015.
10. http://www.alibaba.com/product-detail/200-watt-wind-turbine_1458919538.html?spm=a2700.7724857.35.1.LoIx91 accessed on 21 August, 2015.
11. http://www.linear.com/product/LTC3784 accessed on 20 February, 2015.