



**Harvesting Electrical Energy from Water Supply Tank**

F. ALI<sup>++</sup>, M. N. ARBAB

Department of Electrical Engineering, University of Engineering and Technology, Peshawar

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**Abstract:** Efficiency plays an important role while considering any practical system. Generally electrical means are used to pump water into water supply tanks. At day time the water is allowed to rush through the distribution pipe and is supplied to the consumers. This supply is periodic (almost twice a day) and for a time duration of two hours. In country like Pakistan where we are faced with energy crises its role can be manipulated, and with certain modifications and additions the available potential energy can be utilized to generate electrical power as a byproduct in addition to water supply. This would make the system highly efficient, economical and we would have energy recovery from the system. This energy can be either utilized directly or can be stored in batteries for later use.

**Keywords:** Electrical Energy Harvesting, Potential Energy Storage, Hydroelectric Power Generation, Renewable Energy Systems, Power Generation from Water Tank.

**1. INTRODUCTION**

Energy plays a key role in the development and prosperity of a Nation. Though the development is as a result of multi-disciplinary parameters, generally it has been observed that well developed countries are always self-sufficient in terms of energy and often exports the surplus energy to earn foreign exchange. Energy is the requirement, starting from an ordinary cell operated remote control devices to sewing machines, air conditioners, electrical appliances and other heavy machinery. The systems and equipment that we use in our daily routine life somehow consumes either one or other type energy. Electrical energy in particular would be my focus in the remaining parts of the discussion.

**2. MATERIALS AND METHODS**

**2.1 Technical Background**

Electrical energy consumption is drastically increasing with increase in population and industrial growth. The industries that plays a major role in the development of the country requires bulk amount of energy. From factories to companies, colleges to schools and universities, hospitals to research centers, offices to homes it is all about electricity. The challenge is managing the available fuel, conventional and renewable resources to cope with the demand. Various load forecasting methods have been developed in order to know about the future demands and the predicted development and expansion in the existing energy consuming systems.

Conventionally electrical energy is generated using nuclear, natural gas, Diesel, or coal as fuel. Hydroelectric means is another way of electrical energy. The problem with nuclear, diesel, natural gas, and coal

is that they are not environmentally friendly, have toxic and unhealthy emissions. The modern day researches are emphasizing on moving towards ways of generation that are environmentally friendly and have minimum wastes and emissions.

An important concern is that the reserves are constantly decreasing day by day. A time will come that we would be left with limited conventional resources if we keep on using them without mind or proper planning. The answer to this question is moving towards alternate energy resources such as sun, wind, waves, tides, and pump-hydro structures. Such sources are permanent and inexhaustible. The plus point is that using these types of sources for generation would lead to know or minimum emissions and wastes, the other advantage being re usability.

Another way is using these available resources smartly and managing them to perfection. Water can be used time and again in cycles, to generate electrical power.

**2.2 Related Work**

Pump storage plants are used to provide electrical power in case if it is required to balance the demand and generation. This can also be used to improve the reliability of wind power generation. In this paper (Zhang *et al.*, 2013) works out the capacity that would be required for a pump hydro system to work in coordination with a wind turbine. Operating and investments costs are compared to obtain optimum capacity for a pump storage system. Other parameters are included and their effect on the capacity is determined in this paper.

<sup>++</sup>Corresponding Author *FAHEEM ALI* email: faheem.ali51@gmail.com 0092-91-9216498

(Ela, *et al.*, 2013) elaborates the role of pump storage plants. According to him it's the most popular electrical energy storage system. Previously these plants were used to assist the peak load operation. They used to operate in pump mode at nights to fill the upper reservoirs, while at day time the operation reversed; they were operated in generator mode to generate electrical energy during downward flow. The role of pump hydro storage system has changed in recent years. Earlier being used as storage medium, nowadays the role is manipulated and it is used to assist other plants in power system or is used with other renewable energy systems to generate reliable constant power. Problems that may limit the ability to fully value pumped storage plants are further discussed and solutions to those problems are proposed. The role of pump storage plant to be used as backup or peak hour plant is analyzed and remedies are suggested.

In a case study of Siah Bishe pump storage plant in Iran (Mirsaeidi *et al.*, 2012) addressed load regulation problems. This plant is introduced and analyzed from operational and technical point of view. The author argues that previously the most suited choice for electrical energy storage is pump hydro storage. It used to store water at high potential at off peak periods and then used the potential of the stored water to generate electrical energy at peak load periods. This paper is a survey of the advantages and applications of the pump hydro storage plants. A fair picture for the development of pump hydro storage is disclosed.

Different opportunities for further generation from hydro sources are discussed and focus is on improving the efficiencies of existing systems (Bahadori *et al.*, 2013). Bahadori argues that the hydroelectric is the most mature and reliable generation source, and is implemented worldwide in order to fulfill the energy demands of different communities. The advantage of hydroelectric is that it leaves the fuel intact, not polluting it. Thus it makes it available for further uses and applications.

The new role of hydroelectric generation from low cost generation to a flexible resource offering a number of services has been pointed out by (Snell *et al.*, 2014). Initially hydro-electric generation was considered to be the most economical way of generating electricity at a large scale, recently it has multi-disciplinary applications. It is used as peaking load, as a renewable energy resource as well as low cost "green energy resource". The worth mentioning advantage is a storage medium.

The role of renewable energy sources and its justified implementation is discussed in this paper by

(Nagaraj, 2012). It is generally believed that in far long remote areas independent plant is a more economical solution. The fuel transportation charges to such areas are very high and thus make the overall system uneconomical. Other growing concerns are over the associated climatic changes and global warming. It is therefore advisable to go for independent renewable energy systems, but the main problem is the reliability. This is because all the renewable energy sources have irregular patterns; they vary from region to region and time to time. The availability of these resources is not always ensured when energy is required. Reliability can be considerably improved using hybrid systems, a system consisting of two or more different renewable inputs plus a storage system. The renewable system can be interconnected to a conventional fuel based system as well, so as if one fails due to resource availability, the other one ensures the reliability. Storage system can be added to the existing system, which would store the available energy at times when power availability is greater than the demand. The stored energy can then be utilized at periods of peak demand or when the available power is less than the demand at that time. Fresh water is the other necessity of a community, the main sources of water are the oceans but they have some salinity problem associated with them. The renewable energy systems can be used for desalination of the ocean water providing safe and clean water to the remote areas apart from being used for power generation.

Electrical load in cities are mostly centralized and the energy consumption in the metropolitan area is increasing day by day. If one looks into the list of well developed countries, their energy consumption averages would be much higher compared to the less developed countries. It is because of the associated industrialization, hotels, resorts, factories, street lights, heavy machineries, defense industries, etc. At potential buildings and malls where the height of the building ranges from 30 meters to 300 meters, it is advised to use photo voltaic generation, hydro-electric pump storage system, and grids systems can be used in interconnection to meet the load requirements. At such location there is adequate sunlight availability, water distribution tanks are present at the top of these building and lower reservoirs in the basement can be constructed with ease. Solar panels can be installed at the roof tops, which would generate considerable amount of power. Also the pump storage plants can be used in two different modes, to pump water from lower reservoir to the upper reservoir at off peak periods, and the same water can be allowed to rush through the blades of a reversible machine to generate electrical energy. The generation and consumption trends have been analyzed under different circumstances for three different types of consumers, i.e. residential, commercial, and mixed.

For residential class when the Photovoltaic is available during sunshine or a cloudy day the following sequences have been proposed by (Zhang, J. and Zhang, Q., 2013) (a) At night generation from grid can be used to pump the water from the lower to upper reservoir until it gets full. (b) If there comes a peak hour for grid supply, the potential energy of the water in the upper reservoir can be utilized to generate electrical energy for the building. (c) If the sum of hydro pump and photovoltaic power exceeds the demand of the building, the excess power can be sold to the connected grid. In case the situation is a rainfall, you can use the power from grid as well as the power already stored as potential energy of water. Also the water of rain can be stored as well. For a class of commercial consumers during sunshine or overcast conditions where PV is available the sequences are as follows.

- (a) At night during off peak periods, use the cheaper power that is available from national grid.
- (b) Use power from photovoltaic generator at day time, when sun is shining, to meet the load.
- (c) Allow the water at roof top to generate electrical energy and the upper reservoir to be emptied by the time peak hours of the grid connected supply ends. On rainy days follow the same consequences as discussed for residential class. A similar arrangement pattern for mixed load is also analyzed.

The need for power generation from pump storage plants is increasing day by day worldwide. In rapidly growing economies like china the demand for energy is increasing with time and development is strictly dependent on the power availability. There is need for more pump storage plants in order to balance the demand and supply. It is obvious that these plants are quick in response and can rapidly adjust turbine speed and hence generation in accordance with any shift in demand. This is the most developed scheme and is also used for energy storage in the form of potential energy of water. In recent years Andritz Hydro is making sincere efforts in pump-turbines development. The rapid growth in electrical energy demand calls for more sophisticated and efficient turbine systems. A new turbine using modern tools has been developed for Tongbai project. Testing and analysis has been completed. The phenomena like synchronization, stability are addressed and the unsteady effects are greatly reduced. IN this paper (Nowicki *et al.*, 2009) presents and analyzed the first operational results of the turbine.

A new approach is proposed for load shedding in under frequency conditions using pump storage plants. It is obvious that sometimes there is a sudden dip or dramatic increase in the load, and if the load is not shredded properly, operation at reduced frequency is a

threat to the system. The pump storage plant can be used in two modes, in motor mode when demand is less than generation; it pumps water up into the upper reservoir and acts as a load. On the other hand when the demand is greater than the supply it can be used in the generator mode to increase generation. It can also be used to achieve sensible load shedding in case of sudden load changes. Using pump storages for load shedding and regulation was proposed (Huang, and Huang, 2002).

The role of our system is to produce electrical energy using the potential energy of water stored at a head. But in actual sense it is not the same pump storage plant. Instead a water storage tank is used as an upper reservoir, the prime purpose of the water storage and distribution tank is to supply water to the consumer end efficiently reliably. These systems are widely spread across the world, addressing the water supply issues to the consumer end. A supply tank has fixed domain, in which it has to ensure the water availability for 24 hours a day seven days a week. Normally these supply tanks have sufficient height and that ranges between 20 meters to 100 meters, depending upon the number of consumers and their locations etc. Normally storage and supply tanks supply water to the consumer storage tanks twice or thrice in twenty four hours. And the operation continues for an hour or two each time. This means that the water in the distributor pipes runs every six hours a day, and 180 hours a month. These one hundred and eighty hours can be utilized to produce electrical energy using the downward flow of water in the distributor. The water rushes through the pipes because of the store potential energy which is the converted into potential energy. Two thing are very important considering the capability of generation, one is the head of the storage tank and the other is the discharge of water i.e. the rate at which the water crosses a point each second.

The electrical energy that is produced as a result can be used at the water distribution service provider house or it can be supplied elsewhere. It can also be stored in batteries and can be utilized for other purpose. Unlike pump storage plants where water can be stored and energy can be generated at periods of peak demand, here we can only generate electrical energy when the distributor is carrying pressurized water. It neither depends on peak demand, and we cannot store it in the tank for further use because the distribution of water is scheduled irrespective of power demands of a location. The only time we can generate is when the tank is distributing and the only way to store power is in the form of batteries. It can be stored and then feed back to the motor when it is required to operate as a pump for pumping the water into the tank. This is the energy that is recovered using the energy stored in water. This energy recovery would increase the efficiency of the

system. Though all of the energy cannot be recovered, if we are able to recover even ten per cent, it would be fair achievement. The research theme is therefore energy recovery rather than power generation.

### 2.3 Proposed Model

(Fig.1) show a water supply tank which is fed from a natural reservoir via motor. The motor pumps the water into the storage tank which is later on distributed according to the demand. The kinetic energy of the flowing water is converted into mechanical energy by the turbine. The turbine is couple to alternator via shaft. The alternator converts that mechanical energy in to electrical energy. If the water stored at a potential while distribution is allowed to hit the turbine blades, it would produce electrical energy as a byproduct. The turbine is so designed that the natural flow of water is least affected. The water from the turbine is distributed to domestic water tanks and the energy produced is either utilized directly or can be stored in batteries etc. for later use.

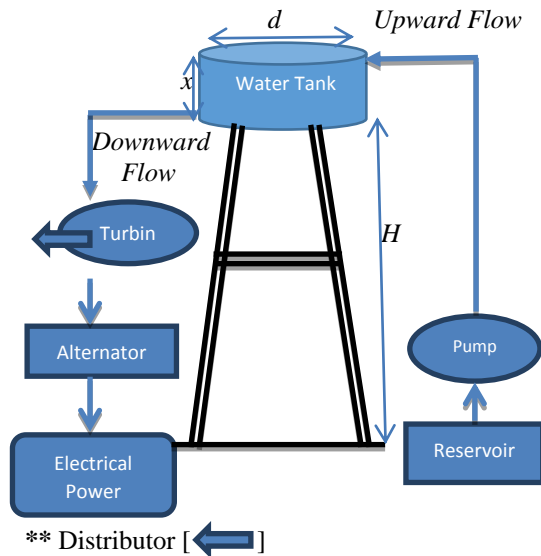


Fig. 1: Water Supply Tank with Energy Recovery

$H$ , head or height of the water storage tank

$d$ , the diameter of the water storage tank

$r$ , Radius of the storage tank

$$r = \frac{d}{2}$$

$x$ , depth of the storage tank

Capacity of the storage tank =  $\pi r^2 x$

Here

$$r = 4 \text{ m}$$

$$x = 5 \text{ m}$$

Capacity of storage tank =  $\pi \times (4)^2 \times 5$

Capacity of storage tank =  $252.43 \text{ m}^3$

Head/ Height of the storage tank =  $20 \text{ m}$

### 2.3.1 Mathematical Analysis

The energy stored in water due to its height from some reference point is known as potential energy. The water in supply tank is stored at a high head. Thus the potential energy stored in water is given by

$$E_h = mgH$$

$E_h$ , represents the hydroelectric energy

$m$ , is the mass of water available in the storage tank

$H$ , is the head or the height of the upper reservoir with respect to turbine

$g$ , is the acceleration due to gravity and its value is  $9.81 \text{ m/s}^2$ .

$$m = \rho V$$

$$E_h = \rho V g H$$

The density of water is equal to  $1000 \text{ kg/m}^3$

Divide both sides of the above equation by time

$$\frac{E_h}{t} = \frac{\rho V g H}{t}$$

$$P_h = \rho Q g H$$

$$P_e = \eta P_h$$

$$P_e = \eta \rho Q g H$$

Efficiency of turbine ranges between 60 and 70 per cent. For the time being we assume it to be around 65 per cent.

$$P_e = 0.65 \times 1000 \times 9.81 \times 20 \times Q$$

$$P_e = 127.53 \times Q \text{ kW}$$

$$Q(ac.) = C_d \times a \times \sqrt{(2gh)}$$

Here

$a$ , is the area of orifice

$C_d$ , is the coefficient of discharge and is equal to the product of coefficient of contraction and coefficient of velocity.

Average value of  $C_c$  is 0.64

Average value of  $C_v$  is 0.97

$h$ , is the height of water level in the storage tank.

Let us take average value of  $C_d$  that is 0.62.

$$a = \pi r'^2$$

$r'$ , is the effective radius of the discharge pipe and is equal to  $0.4 \text{ inch}$ . Water level in the tank varies with time and hence it is kept as it is.

$$Q(ac.) = 0.62 \times 0.0508 \times \sqrt{(2 \times 9.81 \times h)}$$

$$Q(ac.) = 0.02226 \times \sqrt{h} \text{ m}^3/\text{s}$$

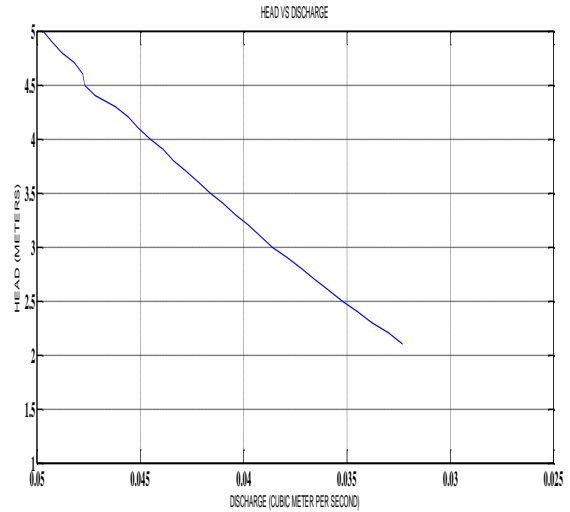
Now it is clear from the above equation that for varying head we have varying discharge. Now for each value of  $h$ , there will be unique value of  $Q$ , and hence unique value of  $P_e$ .

**3. RESULTS AND DISCUSSION**

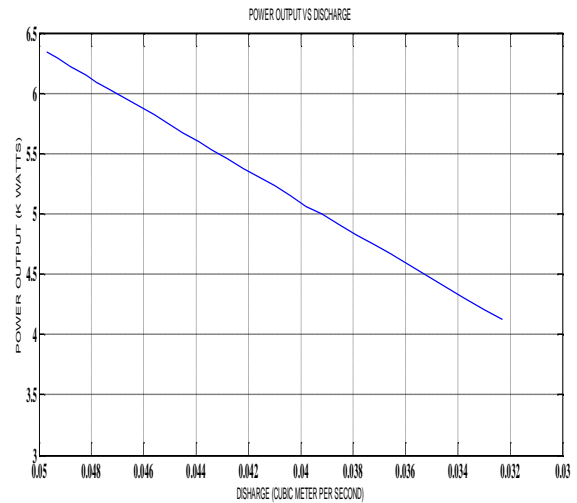
**Table 1** shows the variation of output power against different varying parameters (head, discharge, and time). As the water level in the tank decreases, the discharge also decreases. This is shown in **(Fig. 2)**. In **(Fig. 3)** the output power is plotted against decreasing discharge. It is clear that the power output reduces, as it is directly proportional to the available discharge.

**Table 1: Variation of Output Power W.R.T Head, Discharge and Time**

Time (min)	Head, $h$ (m)	Discharge, $Q$ (m <sup>3</sup> /s)	Power, $P_e$ (kW)
1	5	0.0497	6.34
2	4.9	0.0493	6.29
3	4.8	0.0488	6.22
4	4.7	0.0482	6.15
5	4.6	0.0477	6.08
6	4.5	0.0472	6.02
7	4.4	0.0467	5.95
8	4.3	0.0462	5.89
9	4.2	0.0456	5.82
10	4.1	0.0451	5.75
11	4.0	0.0445	5.67
12	3.9	0.0439	5.60
13	3.8	0.0434	5.53
14	3.7	0.0428	5.46
15	3.6	0.0422	5.38
16	3.5	0.0416	5.30
17	3.4	0.0410	5.23
18	3.3	0.0404	5.15
19	3.2	0.0398	5.06
20	3.1	0.0392	5.00
21	3.0	0.0386	4.92
22	2.9	0.0379	4.83
23	2.8	0.0372	4.74
24	2.7	0.0366	4.67
25	2.6	0.0359	4.58
26	2.5	0.0352	4.49
27	2.4	0.0345	4.40
28	2.3	0.0338	4.31
29	2.2	0.0330	4.21
30	2.1	0.0323	4.12



**Fig. 2: Head vs. Discharge**



**Fig. 3: Power Output vs. Discharge**

The graph of **(Fig. 4)** shows that, the decrease in water level and the corresponding decrease in discharge have affected the power that is to be generated. The power output is continuously decreasing with time which is not desired. Hence the inflow is made equal the outflow and the head is maintained at a constant level in the tank. The following results are obtained.

The graph of **(Fig. 5)** relates output power and time (in case of constant head). Constant head in the tank is achieved when the difference of the inflow and outflow is zero. It is clear that the power output is maintained at a constant level. The efficiency of the system is thus improved and the reliability is ensured.

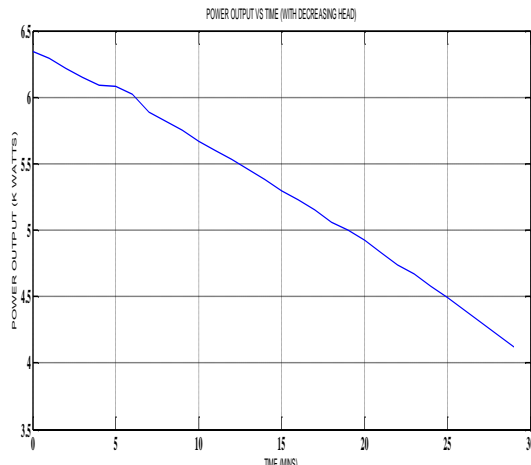


Fig. 4: Power Output vs. Time (Varying Head)

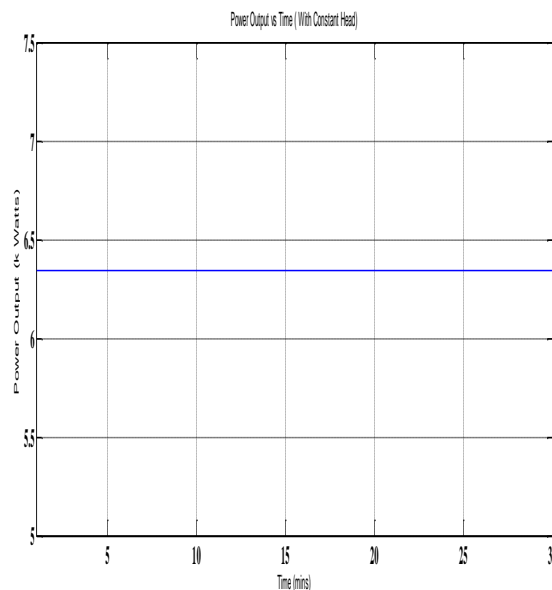


Fig. 5: Power Output vs. Time

#### 4.

#### **CONCLUSION**

The potential energy stored in water is utilized at the time when the distributor is supplying water to the consumer end. Energy is being recovered from the potential energy of water. When the level of water is decreasing in the tank the power output is constantly decreasing. The outflow is so adjusted that the discharge is made equal to the supply which maintains the water and a constant head. More than 6000 watts can be generated using the available head which can be either used directly or can be stored in batteries for later use. The efficiency of the overall system can be improved.

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