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Introducing Pump Storage Scheme to Cope With Peak Load

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***Abstract*—Electrical load demand in Nigeria is greater than the generating capacity. During peak period, load shedding is adopted to prevent system collapse. The off peak period which is predominantly at night is associated with low demand and it is not practicable to shut down large and efficient Generators. The strategy is therefore to starve off the excess water cleave of the load curve to fill the thought. This paper explores the utilization of pump storage scheme as energy storage at off peak period to meet load demand during peak period. The electricity consumption pattern in Nigeria is identified, computation for stored potential energy, pump storage scheme, equivalent electrical power, upper reservoir capacity are performed. The technical details of hydrology system used in the propose scheme is evaluated. Furthermore procedure and economic important of the scheme is discussed in this paper.**

Keywords—Load demand, generating capacity, pump storage scheme, peak period, off peak period

I. INTRODUCTION

Energy is consumed in all activities necessary to support each process in a lifecycle. The electrical energy demand in Nigeria is greater than the generating capacity (Omorogiuwa 2013) resulting to load shedding of major town and villages. Effort is being made however, by the government to solve the epileptic power supply through provision of additional generating stations (Oseweuba 2014).

Another method in addition to provision of extra generating stations includes storing the energy generated at off peak period to meet energy demand during peak period (Nag 2009). This paper suggest the application of pump storage scheme utilising flowing water from catchment area, this water is collected and stored in reservoir at high elevation during off-peak period and made to run to lower elevation through penstock pipe. The stored potential energy is converted to kinetic energy as it gains momentum to the lower level. Using hydro turbine whose shaft is connected to an alternator (Guptar 2007). The kinetic energy is converted to electrical energy to meet extra load demand during peak period.

Load demand curve

Load curve is a graphical representation of load demand in MW with respect to time in Hour (Nagrah 1994) in a grid system. The load curve shows the variation of load on the grid system .the load on a power network is never constant. It varies from time to time (Banl 2006) (Nagrath 1994).

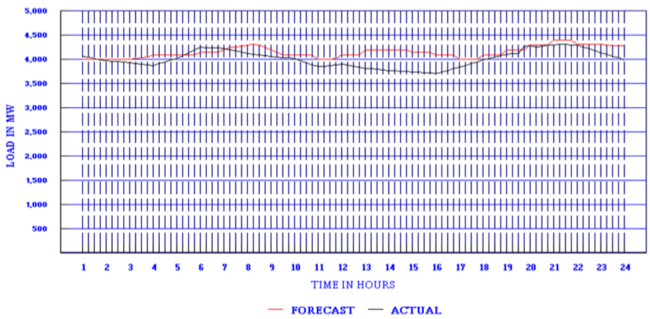


Figure 1 A load curve showing forecast-actual demands deviations

MODEL OF 380KW PUMP STORAGE SCHEME

Pump Storage Scheme;

Stored energy can be accomplished by pumping water from a lower reservoir to a higher one (Shama 2007) and held back, during off peak period which is generally at night creating a stored energy. The stored energy is converted to electrical energy by allowing the water to flow down the height through large steal lined pipe (penstock) during the peak demand time. During off peak period the generator operate as motor driving the turbine in a pumping mode. It is not practicable to shut down large and efficient generator at night (Sawhwey 2006) hence are kept “On line” supplying relatively small load during this period the pumping power will be supplied at low incremental cost (Nag 2009). At peak demand the pump storage scheme provide power to meet load demand.

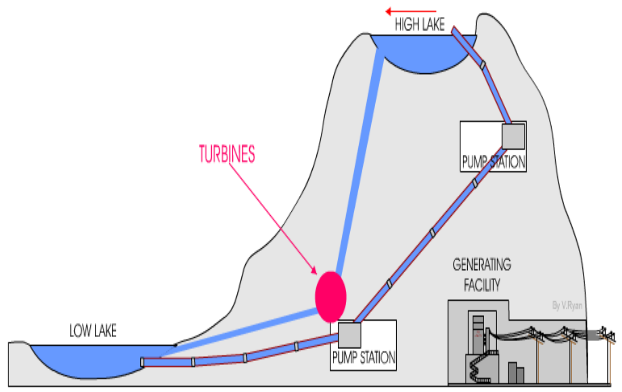


Figure 2 Schematic Diagram of Pump storage scheme

Component of pump storage scheme (Ral2009), (Shama 2007)

- Reservoir – An important structure to store (Rajput 2005) water for creating head and to assure the continuous flow of water
- Penstock - a pipe from the fore bay of the reservoir serving as water conducing system
- Turbine - The mechanical installation that convert stored potential energy of water to rotational kinetic energy
- Alternator - an electro mechanical transducer that convert rotational kinetic energy into electrical energy
- Power House - A civil structure used for housing electro mechanical installation.

Computation of system hydrology power

The power of the runner is computed from the stored energy (Shama 2007) (Rayput 2005) (Nay 2009)

P = Q H Yn ℓ g K (1)

Q = discharge $m^3/3$

H = gross head (m)

Yn = Hydraulic efficiency

g = gravitational force

ℓ = Density of water kg/m^3

K = efficiency of Turbine = 0.9

Mass of 1 m^3 of water is 1000 kg

H = 6.65 (chosen)

Y = 0.9

Q = 6.55 m^3 (chosen)

P = 385kw

Speed of turbine

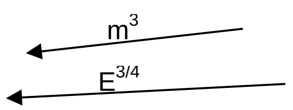
Specific speed

$$nQ_{\epsilon} = \frac{n + \sqrt{Q}}{E^{3/4}} \quad (2)$$

ε = specific hydraulic energy of machine

n = rotational speed of turbine per second (Rayput 2005 Ral 2007)

E = Hn g (3)



Hn = Net Head (m)

Net head = Head x efficiency (Rayput 2005 Ral 2007)

Hn = H x Yn (m) (4)

Hn = 6.66 x 0.9 = 5. 99 ≈ 6m

The correlation between net head and specific speed for Kaplan turbine is given by (Ral 2007) (Ragput 2005) (Nag 2009)

$$nQ_{\epsilon} = \frac{2.294}{Hn\ 0.486} \quad (5)$$

Rotational speed of turbine

Substitution equation 3 in equation 2

Rotational speed obtained = 7.98 s^{-1}

Generator synchronous speed

This is a function of the number of pole in the alternator and the coupling device between Alternator and turbine

$$Ns = \frac{M\sqrt{P}}{H\ 5/4} \quad (6)$$

Expected output is 50Hz frequency

This help to selecting the type and speed of turbine. Normal running speed can be determine if specific speed is known (Ral 2007) (Ragput 2005) (Nag 2009)

Runner diameter

$$De = 84.5\ (0.79 \times 1.602 \times NQ\varepsilon)\ \frac{\sqrt{Hn}}{60xn} \quad (7)$$

De = 1.01

Hub diameter

D_L = (0.25 x 0.0951/ nQε) x De (Nag, 2009) (8)

D_L = 0. 31

Size of reservoir

Discharge = 6.55 m^3/s

For 5 Hours duration = 6.55 x 3600x 5 = 177.900 m^3

Evaporating factor not considered.

CONCLUSION

Tall rock close to river sources can be used as embankment; it can be scooped by tall concrete parapet wall and lined with reinforced concrete to serve as upper reservoir for the Pump Storage Scheme (PSS). The pump turbine technology needs to be put in use to meet power need and enhance reliability availability of power at peak period. The scheme enables fast grid primary control and reduce the amount of load demand that experience shedding, minimum environmental impart, and increase power capacity and efficient peak power generation is obtained with the application of this scheme. This model can be duplicated in multiple for more power output.

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