International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Hydro Power Plant

Desai Ritesh Rajendra[a], Pawar Aniket Anil[b] ,Desai Mayur Shankar[c] ,Sarvade Siddhivinayak Dattatray[d],Misal Nikhil Nivas[e],Jadhav Prathamesh Dipak[f]

[abcdef] Students,Electrical Engineering,NMPI,PETH,415407,INDIA

ABSTRACT :

Hydropower plants play a pivotal role in the global energy landscape, offering a renewable and sustainable source of electricity generation. The focus of this report is on the design, operation, environmental impact, efficiency, and maintenance of hydropower plants, with particular emphasis on their role in energy storage and peak power generation. Understanding the intricacies of this energy storage and peaking power generation process is crucial for optimizing the performance of hydropower plants and integrating them effectively into the broader energy grid. By examining the design principles, operational strategies, environmental considerations, efficiency factors, and maintenance protocols associated with hydropower plants, this paper aims to provide a comprehensive overview of their role in sustainable energy production and storage.

Keywords: SISO-Single Input Single Output,MIMO-Multiple Input Multiple Output,PID-Proportional Integral Derivative

Introduction :

Hydropower harnesses the energy of moving water to generate electricity. Water flowing through rivers or released from reservoirs spins turbines, converting the kinetic energy into mechanical energy. Generators then convert this mechanical energy into electricity.

As the water source is replenished by the natural water cycle, hydropower is considered a renewable energy source. It plays a crucial role in reducing dependence on fossil fuels and mitigating greenhouse gas emissions, contributing to a cleaner and more sustainable energy future.

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation and 3,427 terawatt-hours of electricity production in 2010,[1] and is expected to increase about 3.1% each year for the next 25 years. Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. There are now three hydroelectricity plants larger than 10 GW: the Three Gorges Dam in China, the Itaipu Dam across the Brazil/Paraguay border, and the Guri Dam in Venezuela. The cost of hydroelectricity is relatively low, making it a competitive source of renewable electricity. The average cost of electricity from a hydro plant larger than 10 megawatts is 3 to 5 U.S. cents per kilowatt-hour [1] Hydro is also a flexible source of electricity since plants can be ramped up and down very quickly to adapt to changing energy demands. However, damming interrupts the flow of rivers and can harm local ecosystems, and building large dams and reservoirs often involves displacing people and wildlife. Once a hydroelectric complex is constructed, the project produces no direct waste and has a considerably lower output level of greenhouse gas carbon dioxide (CO_2) than fuel-powered energy plants.

History of Hydropower Plant :

Humans have been harnessing water to perform work for thousands of years. The Greeks used water wheels for grinding wheat into flour more than 2,000 years ago. Besides grinding flour, the power of the water was used to saw wood and power textile mills and manufacturing plants. For more than a century, the technology for using falling water to create hydroelectricity has existed. The evolution of the modern hydropower turbine began in the mid-1700s when a French hydraulic and military engineer, Bernard Forest de Bélidor wrote Architecture Hydra Lique. In this four-volume work, he described using a vertical-axis versus a horizontal-axis machine. During the 1700s and 1800s, water turbine development continued. In1880, a brush arc light dynamo driven by a water turbine was used to provide theatre and storefront lighting in Grand Rapids, Michigan; and in 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York. These two projects used direct-current technology. Alternating current is used today. That breakthrough came when the electric generator was coupled to the turbine, which resulted in the world's, and the United States', first hydroelectric plant located in Appleton, Wisconsin, in 1882.

In the 19th century, French engineer Benoît Fourneyron developed the first hydropower turbine. This device was implemented in the commercial plant of Niagara Falls in 1895 and it is still operating.[11] In the early 20th century, English engineer William Armstrong built and operated the first private electrical power station which was located in his house in Cragside in Northumberland, England.[11] In 1753, the French engineer Bernard Forest de Bélidor published his book, Architecture Hydraulique, which described vertical-axis and horizontal-axis hydraulic machines.[13]

The growing demand for the Industrial Revolution would drive development as well.[12] At the beginning of the Industrial Revolution in Britain, water was the main power source for new inventions such as Richard Arkwright's water frame.[13] Although water power gave way to steam power in many of the larger mills and factories, it was still used during the 18th and 19th centuries for many smaller operations, such as driving the bellows in small blast furnaces (e.g. the Dyfi Furnace) and gristmills, such as those built at Saint Anthony Falls, which uses the 50-foot (15 m) drop in the Mississippi River. Technological advances moved the open water wheel into an enclosed turbine or water motor. In 1848, the British-American engineer James B. Francis, head engineer of Lowell's Locks and Canals company, improved on these designs to create a turbine with 90% efficiency.[15] He applied scientific principles and testing methods to the problem of turbine design. His mathematical and graphical calculation methods allowed the confident design of high-efficiency turbines to exactly match a site's specific flow conditions. The Francis reaction turbine is still in use. In the 1870s, deriving from uses in the California mining industry, Lester Allan Pelton developed the high-efficiency Pelton wheel impulse turbine, which used hydropower from the high-head streams characteristic of the Sierra Nevada.

The modern history of hydropower began in the 1900s, with large dams built not simply to power neighboring mills or factories[16] but to provide extensive electricity for increasingly distant groups of people. Competition drove much of the global hydroelectric craze: Europe competed amongst itself to electrify first, and the United States's hydroelectric plants in Niagara Falls and the Sierra Nevada inspired bigger and bolder creations across the globe.[17] American and USSR financers and hydropower experts also spread the gospel of dams and hydroelectricity across the globe during the Cold War, contributing to projects such as the Three Gorges Dam and the Aswan High Dam. Feeding the desire for large-scale electrification with water inherently required large dams across powerful rivers, which impacted public and private interests downstream and in flood zones. Inevitably smaller communities and marginalized groups suffered. They were unable to successfully resist companies flooding them out of their homes or blocking traditional salmon passages.[11] The stagnant water created by hydroelectric dams provides a breeding ground for pests and pathogens, leading to local epidemics. However, in some cases, a mutual need for hydropower could lead to cooperation between otherwise adversarial nations.

Hydropower technology and attitude began to shift in the second half of the 20th century. While countries had largely abandoned their small hydropower systems by the 1930s, the smaller hydropower plants began to make a comeback in the 1970s, boosted by government subsidies and a push for more independent energy producers.[19]Some politicians who once advocated for large hydropower projects in the first half of the 20th century began to speak out against them, and citizen groups organizing against dam projects increased.

In the 1980s and 90s, the international anti-dam movement had made finding government or private investors for new large hydropower projects incredibly difficult, and given rise to NGOs devoted to fighting dams. Additionally, while the cost of other energy sources fell, the cost of building new hydroelectric dams increased by 4% annually between 1965 and 1990, due both to the increasing costs of construction and the decrease in high-quality building sites. In the 1990s, only 18% of the world's electricity came from hydropower. Tidal power production also emerged in the 1960s as a burgeoning alternative hydropower system, though still has not taken hold as a strong energy contender.

3.Design methodology

5.1 3.1 Introduction of Hydropower Plant

Hydropower, also known as water power, is the use of flowing or fast-moving water to generate electricity or power machinery. This is done by converting the energy from the water's movement into usable power. It's a sustainable method of energy production because it doesn't deplete natural resources. Hydropower is mostly used for generating electricity through hydroelectric power plants. It can also be part of a system called pumped-storage hydroelectricity, which stores energy for later use. One of the key advantages of hydropower is its environmental friendliness. Unlike fossil fuels, it doesn't produce harmful emissions like carbon dioxide. Additionally, it provides a consistent source of power, which helps stabilize the energy supply.

However, there are challenges associated with hydropower. It requires a reliable and energetic source of water, such as a river or a lake. There can also be economic, social, and environmental concerns, such as the impact on local ecosystems and communities. Historically, hydropower has been used for various purposes, including irrigation and powering mechanical devices like mills and cranes. Even today, it remains an important renewable energy source with potential for economic development, according to organizations like the World Bank.

The role of hydropower as a renewable energy source is significant for several reasons:

1. Abundant Resource: Water, the primary source of hydropower, is abundant and readily available in many regions, making hydropower a reliable and consistent source of energy.
2. Low Greenhouse Gas Emissions: Hydropower plants produce minimal greenhouse gas emissions compared to fossil fuel-based power plants. This reduces the carbon footprint and helps mitigate climate change.
3. Renewable and Sustainable: Hydropower is renewable because it relies on the continuous cycle of water evaporation, precipitation, and runoff. When managed properly, hydropower can be sustained indefinitely, providing long-term energy security.

4. Versatility and Flexibility: Hydropower plants can be designed to provide both base load and peaking power, offering flexibility to adapt to fluctuations in energy demand. This versatility makes hydropower an integral part of a diversified energy portfolio.
5. Storage and Grid Stability: Hydropower reservoirs serve as energy storage systems, allowing excess energy to be stored during periods of low demand and released during peak demand. This helps stabilize the grid and ensures a reliable power supply.
6. Environmental Benefits: Hydropower plants have a relatively low environmental impact compared to other forms of energy generation. Properly managed hydropower projects can mitigate the risk of flooding, enhance water management, and provide habitat for aquatic species.

Overall, hydropower plays a vital role in the transition to a sustainable energy future by providing clean, renewable, and reliable electricity generation. It complements other renewable energy sources and contributes to reducing dependence on fossil fuels while mitigating environmental impacts.

5.2 3.2 Types of Hydropower Plants

Hydropower plants come in various configurations, each suited to specific geographical features and energy needs. Here's a breakdown of the main types:

5.3 Run-of-River Hydropower Plant

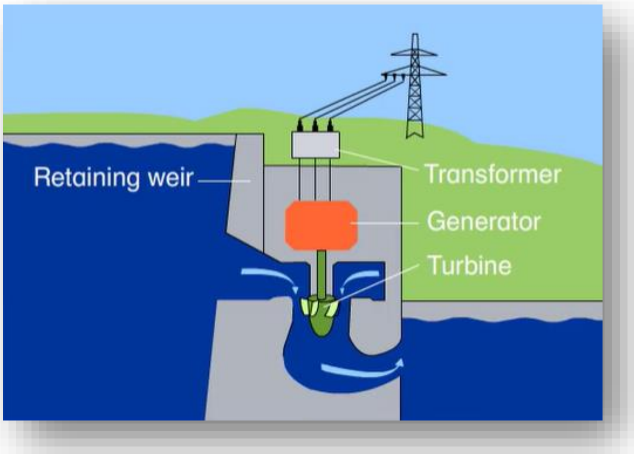

Figure 3.1 Run of river hydropower plant

These plants utilize the natural flow of a river without requiring dams. Water is diverted through a canal or penstock to spin turbines and generate electricity. Run-of-river plants have minimal or no water storage capacity. Electricity generation fluctuates with the river's flow rate. Locations with consistent river flow and smaller-scale power requirements.

5.4 Reservoir (Conventional) Hydropower Plants

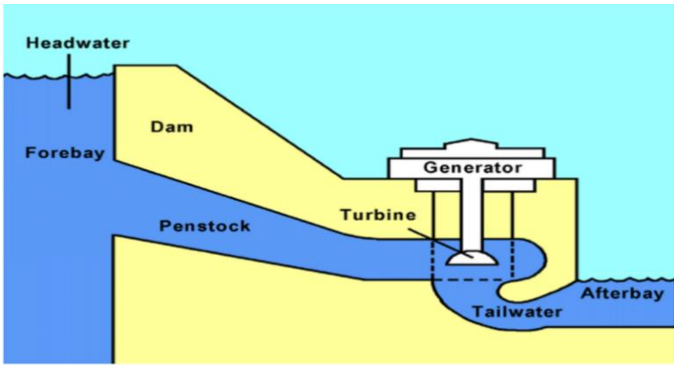

Figure 3.2 Reservoir (conventional) hydropower plant

Conventional hydropower plants, also known as reservoir hydropower plants, harness the power of moving water stored behind a dam to generate electricity

5.5 Pumped Storage Hydropower Plants

5.6

5.7

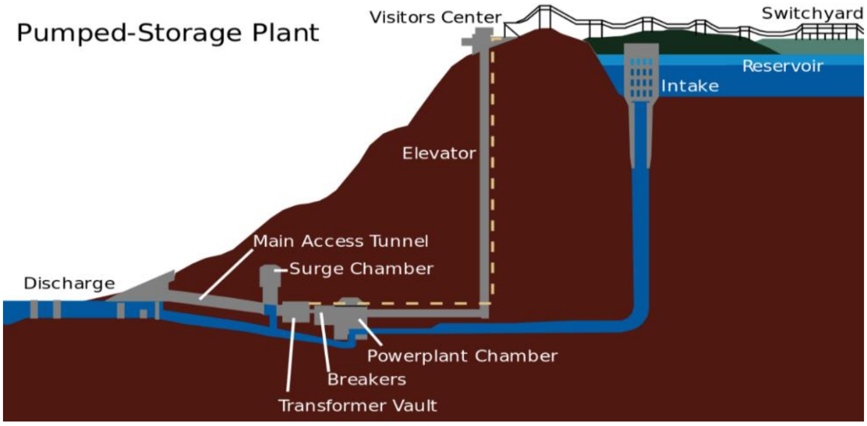

Figure 3.3 Pumped storage hydropower plant

Pumped storage hydropower plants function like giant batteries, storing energy during off-peak hours and generating electricity during peak demand periods.

5.8 Working of Hydropower Plant

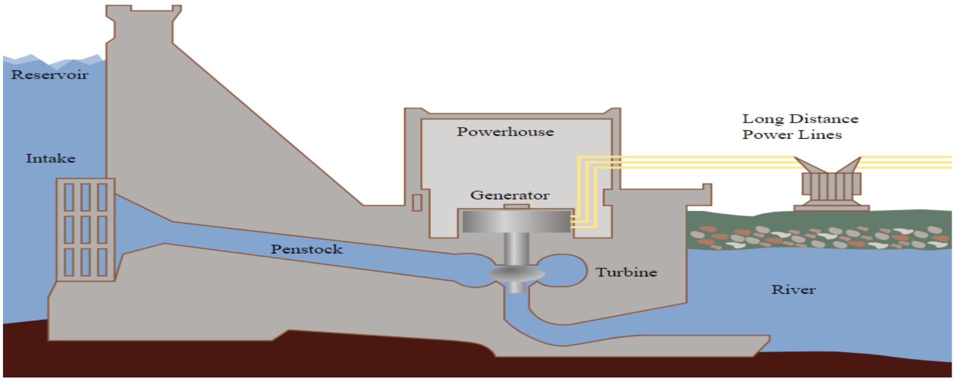

Figure 3.4 Hydropower Plant

The working of a hydropower plant involves several key components, each playing a crucial role in the process of generating electricity from flowing water.

In summary, the working of a hydropower plant involves harnessing the energy of flowing water to rotate turbines, which in turn drive generators to produce electricity. The components of the plant, including the reservoir, intake, penstock, powerhouse, generator, turbine, river, and long-distance power lines, all play essential roles in this process.

4.Scope of the System

The scope of hydropower plants encompasses various aspects, including energy generation, economic development, environmental sustainability, and technological advancements. Here's a detailed look at each aspect:

1. **Energy Generation:**
    - Hydropower plants have significant potential for electricity generation, providing a reliable and renewable source of energy.
    - The scope includes harnessing the energy from flowing water to produce electricity, contributing to meeting the growing global energy demand.
2. **Economic Development:**
    - Hydropower projects can stimulate economic growth by creating job opportunities during the construction and operation phases.
    - They also contribute to local and national economies through revenue generation from electricity sales and infrastructure development.
3. **Environmental Sustainability:**
    - Hydropower is considered a clean and sustainable energy source with minimal greenhouse gas emissions.
    - The scope includes mitigating climate change by reducing reliance on fossil fuels and promoting environmentally friendly energy

alternatives.

4. **Technological Advancements:**
   - Ongoing research and development in hydropower technology aim to improve efficiency, reduce environmental impact, and enhance overall performance.
   - The scope encompasses innovations in turbine design, control systems, materials, and construction techniques to optimize hydropower plant operation.

5. **Water Resource Management:**
   - Hydropower plants play a role in water resource management by regulating river flows, controlling flooding, and providing water for irrigation and domestic use.
   - The scope includes balancing the needs of energy generation with the sustainable use of water resources and ecosystem preservation.

6. **Grid Stability and Energy Security:**
   - Hydropower plants contribute to grid stability by providing baseload power and flexibility in response to demand fluctuations.
   - The scope includes integrating hydropower into the energy grid to enhance reliability, resilience, and energy security.

7. **Social and Community Impacts:**
   - Hydropower projects can have social and community impacts, both positive and negative.
   - The scope includes addressing social issues such as the resettlement of affected communities, land rights, cultural heritage preservation, and stakeholder engagement.

8. **Global Perspective:**
   - Hydropower has a global scope, with potential for development in various regions, including emerging economies and remote areas with abundant water resources.
   - International cooperation and investment in hydropower projects contribute to sustainable development goals and energy access initiatives worldwide.

In summary, the scope of hydropower plants extends beyond electricity generation to encompass economic, environmental, social, and technological dimensions. By leveraging the potential of hydropower, societies can achieve multiple benefits, including clean energy, economic growth, and environmental sustainability.

Results

This report explored the concept and operation of [type of hydropower plant] for clean and renewable electricity generation. Hydropower offers significant advantages, including minimal greenhouse gas emissions, reliable power generation (for reservoir plants), and the potential for additional benefits like flood control and irrigation. However, it's important to acknowledge the environmental impacts of dam construction and the limitations of finding suitable locations for new hydropower plants.

Our exploration of reservoir hydropower plants revealed their compelling strengths: reliable power generation, large-scale electricity production, and the potential for additional benefits. However, the high initial costs and environmental impact of dam construction require careful consideration.
Globally, reservoir hydropower plants play a critical role in electricity generation. For instance, this project demonstrates the capability of these plants, to generate significant clean energy while providing additional benefits. Looking ahead, advancements in technology and sustainable practices offer promising opportunities. By optimizing dam design, implementing responsible management strategies, and integrating hydropower with other renewables, we can unlock the full potential of reservoir hydropower in a clean and sustainable energy future.

Applications

5.9 Primary Application: Reliable Electricity Generation

1. Meeting Peak Demand: Reservoir hydropower excels at providing reliable and predictable electricity generation. The ability to control water flow from the reservoir allows for power generation on demand, making them crucial for meeting peak demand periods when electricity consumption is high.
2. Grid Stability: These plants contribute significantly to grid stability by providing a quick and sizeable source of electricity to address sudden fluctuations in demand. This helps to maintain the consistent flow of electricity in the power grid.
3. Large-Scale Power Generation: Reservoir hydropower plants are capable of generating massive amounts of electricity, making them a substantial source of clean energy for powering cities and industries.

5.10 Secondary Applications: Beyond Electricity

1. Flood Control: Dams associated with reservoir plants serve a crucial function in flood control. By regulating water flow during periods of heavy rainfall, they can significantly reduce the risk of flooding downstream, protecting communities and infrastructure.
2. Irrigation: Reservoirs can provide a valuable source of water for irrigation purposes. Stored water can be released during dry seasons, ensuring a reliable water supply for agricultural activities.
3. Navigation: Dams can improve river navigation by maintaining water levels, and creating deeper channels for barges and other waterborne vessels.
4. Recreation: Reservoirs often become popular recreational destinations, offering opportunities for activities like boating, fishing, and swimming. These activities can contribute to local tourism and economic development..

Conclusion

Reservoir (conventional) hydropower plants offer a potent combination of clean energy generation, grid stability, and potential for additional benefits. This report has explored their core functionalities, highlighting their strengths:

Reliable Electricity Generation: The controlled water flow from reservoirs allows for dependable power production on demand, meeting peak demand periods and contributing to grid stability.

Large-Scale Power Production: These plants can generate significant amounts of electricity, serving as a substantial source of clean energy for powering communities.

Additional Benefits: Dams associated with reservoirs can contribute to flood control, irrigation, navigation, and even recreation, offering value beyond electricity generation.

However, the report also acknowledged the limitations of reservoir hydropower, including high initial costs and potential environmental impacts.

Looking ahead, advancements in dam design and responsible reservoir management practices are crucial for minimizing these drawbacks. The potential integration of reservoir hydropower with other renewable energy sources like solar and wind presents exciting possibilities for creating a more robust and sustainable energy future. Reservoir hydropower plants continue to play a vital role in our global energy mix. By harnessing the power of moving water, they provide clean energy while offering additional benefits for communities. As we strive for a sustainable energy future, ongoing technological advancements, responsible practices, and integration with other renewable sources can unlock the full potential of reservoir hydropower for generations to come.

REFERENCES :

1 Karady, G. G. and Holbert, K. E. Electric Generating Stations, in Electrical Energy Conversion and Transport: An Interactive Computer-Based Approach, Second Edition, John Wiley & Sons, Inc. 2013.

[2] Naghizadeh, R.A., Jazebi, S. and Vahidi, B. Modelling Hydro Power Plants and Tuning Hydro Governors as an Educational Guideline. International Review on Modelling and Simulations (I.RE.MO.S), Vol. 5, No. 4 2012.

[3] IEEE Committee. Dynamic models for steam and hydro turbines in power system studies. IEEE Trans on Power Appar Syst; 92:1904–15, 2003

[4] IEEE Working Group. Hydraulic turbine and turbine control models for system dynamic studies. IEEE Trans on Power Syst;7:167–79, 1992.

[5] Vournas CD. Second-order hydraulic turbine models for multimachine stability studies. IEEE Trans Energy Conv 1990;5: 239–44. ARTICLE IN PRESS 792 N. Kishor et al. / Renewable and Sustainable Energy Reviews 11,776–796, 2007.

[6] Qijuan C, Zhihuai Xiao. Dynamic modeling of hydroturbine generating set. In: IEEE International Conference on Systems, Man and Cybernetics, pp. 3427– 3430, 2000.

[7] Singh, M., and Chandra, A. Modeling and Control of Isolated Micro-Hydro Power Plant with Battery Storage System. National Power Electronic Conference, Roorkee, India 2010.

[8] Malik, O.P., Hope, G. S., Hancock, G., Zhaohui, L., Luqing, Y. E. and Shouping, W. E. I. Frequency measurement for use with a microprocessor-based water turbine governor. IEEE Trans Energy Conv, 6:361–6, 1991.

[9] Ramey, D. G. and Skooglund, J. W. Detailed hydro governor representation for system stability studies. IEEE Trans on Power Apparatus and Systems, 89:106–12, 1970.

[10] Bhaskar, M. A. Non Linear Control of STATCOM. IEEE Internaltional Conference on Recent Trends in Information Telecommunication and Computing, pp. 190-195, 2010.

[11] Luqing, Y. E., Shouping, W. E. I., Malik, O. P. and Hope, G. S. Variable and time varying parameter control for hydroelectric generating unit. IEEE Trans Energy Conv, 4:293–9, 2000.

[12] Fuchs, E. F. and Masoum, M.A.S. 2011. Power Conversion of Renewable Energy Systems, Springer, ISBN 978-1-4419-7978-0 [14] Hernandez, G. A. M., Mansoor, S. P. and Jones, D. L. 2012. Modeling and Controlling Hydropower Plants, Springer, DOI 10.1007/978-1-4471-2291-312.

[13] Xu, F., Li, Y. and Qijuan, C. Study of the Modelling of Hydroturbine Generating Set. In: International IEEE/IAS Conference on Industrial Automation and Control: Emerging Technologies, 22-27, pp. 644-647. 1995.

[14] Hernandez, G. A. M., Mansoor, S. P. and Jones, D. L. Modelling and Controlling Hydropower plants, Springer, DOI 10.1007/978-1-4471-2291-312, 2012.

[15] Marquez, J. L., Molina, M. G. and Pacas, J. M. Dynamic modeling, simulation and control design of an advanced micro-hydro power plant or distributed generation applications.” Elsevier Trans. On Hydrogen Energy Policy, I-6, 2010.

[16] Nassar, I. A., Weber, H. Dynamic Model of Unit 1 of Ataturk Hydro Power Plant in Turkey. 13th Middle East Power Systems Conference, MEPCON’ Assiut University, Egypt , 2009.

[17] Singh, G., and Chauhan, D. S. Simulation and Modeling of Hydro Power Plant to Study Time Response during Different Gate States. (IJAEST) INTERNATIONAL JOURNAL OF ADVANCED ENGINEERING SCIENCES AND TECHNOLOGIES Vol. No . 10, Issue No. 1, 042 – 047, 2011.

[18] Munoz-Hernandez, G. A. and Jones, D. I. 2004, Modelling, Simulation and Control of a Hydroelectric Pumped Storage Power Station, Control University of Bath, UK, 2004.

[19] Prillwitz, F., Al-Ali, S. E., Haase, T., Weber, H. and Saqe, L. Simulation Model of the Hydropower plant Shkopeti. 6th EUROSIM Congress on Modelling and Simulation, Ljubljana, Slovenia, 2007.

[20] Zagona, E. A. and Magee, T. M Modelling Hydropower in RiverWare. In Proc. of Waterpower 99: Hydro’s Future: Technology, Markets and Policy, pp 1- 10, 2013.

[21] [21] IEEE Working Group on Prime Mover and Energy Supply Models for System Dynamic Performance Studies. 1992. Hydraulic Turbine and Turbine Control Models for Dynamic Studies. IEEE Transactions on Power Systems, Vol.7, No.1, pp. 167-179.

[22] Mathworks. 2014. Synchronous Machines. http://www.mathworks.com/examples/simpower/50- synchronous-machine.

[23] Kishor, N., Sainia, S. P. and Singh, S. P. A review on hydropower plant models and control. Science Direct, Review of Sustainable Energy Review, Elsevier, pp. 776-796. 2006.