The Role of Internet of Things (IoT) in Hydel Energy Sector- Perspectives

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Abstract. The integration of renewable energy and the optimization of energy use are crucial components of sustainable energy transitions aimed at mitigating climate change. Modern technology, notably the Internet of Things (IoT), offers a myriad of applications within the energy sector, spanning energy supply, transmission and distribution, and demand. IoT holds the potential to enhance energy efficiency, boost the share of renewable energy sources, and reduce the environmental impact of energy consumption. This review article synthesizes existing literature on IoT applications in Hydelenergy systems, with a particular focus on smart grids. Furthermore, it delves into the enabling technologies of IoT, including cloud computing and data analysis platforms. Challenges in deploying IoT in the energy sector, such as privacy and security concerns, are also addressed, with proposed solutions like blockchain technology. This review serves as a comprehensive resource for energy policymakers, economists, and managers, providing insights into IoT's role in optimizing policymakers, economists, and managers, providing insights into IoT's role in optimizing energy systems.

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1 Introduction

The human society has witnessed four industrial revolutions, of these the recent one is the fourth Industrial revolution which relies heavily on amalgamation of Artificial Intelligence (AI), Big Data and Internet of Things (IoT) [1]. The emergence of the Internet of Things (IoT) can be traced back to the early 1980s, when a group of students at Carnegie Mellon University modified a Coca-Cola vending machine to track its contents remotely. However, the technology was bulky and expensive at the time, and it wasn't until the late 1990s that the IoT began to take off [2]. In 1999 Kevin Ashton had coined the term "Internet of Things" in a presentation to Procter & Gamble [3]. In his presentation he envisioned a world where everyday objects would be equipped with sensors and connected to the internet, allowing them to collect and share data. The IoT began to gain traction in the early 2000s with the advent of cheaper and more powerful sensors, as well as the development of wireless communication protocols such as ZigBee and Bluetooth [3]. This led to the development of a wide range of IoT devices, including smart home devices, wearable devices, and industrial sensors.
In 2011, Google acquired Nest Labs, a maker of smart thermostats. This acquisition was seen as a sign of Google's commitment to the IoT, and it helped to raise the profile of the technology [4]. In recent years, the IoT has continued to grow rapidly. The number of connected devices is expected to reach twenty-seven percent increase [5].

2 IoT in Renewable Grids

The Internet of Things (IoT) is playing an increasingly important role in renewable energy grids. IoT devices can be used to monitor and control renewable energy assets, such as solar panels and wind turbines, as well as to integrate renewable energy into the broader grid.
One of the key benefits of using IoT in renewable grids is that it can help to improve efficiency. [6] For example, IoT sensors can be used to track the performance of solar panels and wind turbines, and this data can be used to identify and fix any problems that may arise. IoT devices can also be used to automate the cleaning and maintenance of renewable energy assets, which can further reduce costs. Another benefit of using IoT in renewable grids is that it can help to improve reliability. For example, IoT sensors can be used to monitor the weather conditions and the grid load, and this data can be used to predict when renewable energy output will be low. This information can then be used to dispatch conventional power plants or to store energy in batteries, so that the grid can continue to operate reliably even when renewable energy output is low. IoT is also being used to integrate renewable energy into the broader grid. For example, IoT devices can be used to manage the flow of electricity between renewable energy assets and the grid [12]. This can help to ensure that the grid remains stable even when the output of renewable energy sources is fluctuating. Overall, IoT is helping to make renewable energy grids more efficient, reliable, and integrated. As the technology continues to develop, we can expect to see even more innovative and groundbreaking IoT applications in the renewable energy sector in the years to come.

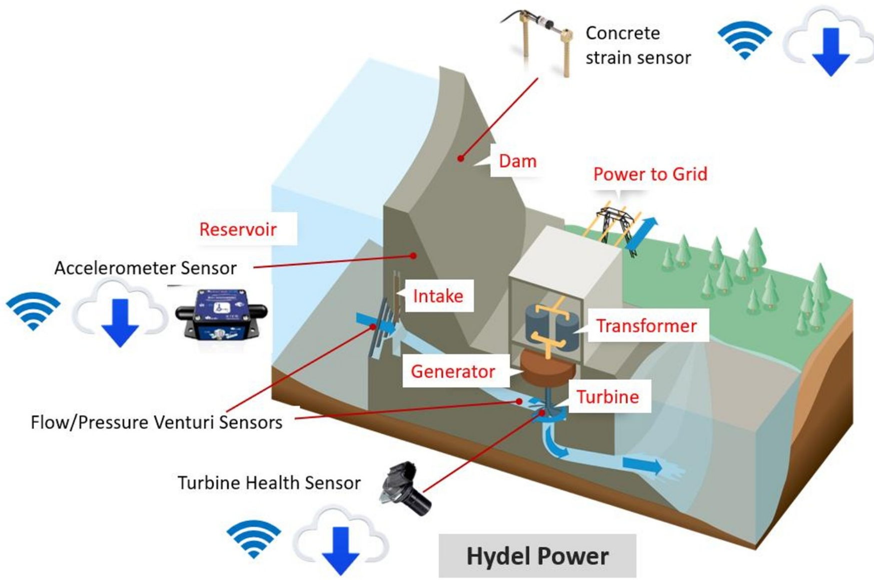

Figure.1. Hydel/Hydro Power Grids

3 IoT in Hydel Power/Hydropower

The fig.1 and table 1 lists the key sensors that can be connected to the internet and the cloud for continuous monitoring. By connecting these sensors to the internet and the cloud, plant operators can remotely monitor the health and performance of the hydel power plant in real time. This information can be used to identify and address potential problems early on, before they cause major damage or disruption to operations.

- *Temperature sensors*: Can be used to monitor the temperature of the dam structure, turbines, and other equipment. This information can be used to identify potential problems such as overheating or hot spots.
- *Humidity sensors*: Can be used to monitor the humidity levels in the dam structure and other areas of the plant. This information can be used to identify potential problems such as corrosion or mold growth.
- *Air quality sensors*: Can be used to monitor the air quality in the plant and surrounding areas. This information can be used to identify potential problems such as air pollution or gas leaks.

By combining data from a variety of sensors, plant operators can gain a comprehensive understanding of the health and performance of the hydel power plant. This information can be used to optimize operations, improve safety, and reduce costs.

Table 1. Hydel power plant-Sensor Systems and Applications [7-11]

Sensor	Application	Details
Concrete Strain Sensor	Concrete strain measurement	Measures the strain the dam is withstanding in real-time

Accelerometer Sensor	Vibration Measurements	evaluate the displacement or articulation of the dam structure using the information acquired from the accelerometers which are fixed on the dam's crest, heel and toe
Flow/Pressure sensors	Water Flow measurement/ Pressure	Flow sensors are able to detect leaks, blockages, pipe bursts, and changes in water volume etc. Rate of change of water volume
Turbine Health Monitoring Sensors	Structural integrity, Vibrations etc.	Typically Vibration Meters with the ability to measure Vibration Amplitude in terms of Velocity and Displacement

4 Future Scope of Research

The integration of the Internet of Things (IoT) into the energy sector, particularly in the realm of hydel energy, has opened up a plethora of opportunities for further exploration. The following pointers highlight potential areas of research that can be pursued to further harness the capabilities of IoT in the hydel energy sector:

- **Advanced Sensor Integration**: With the current use of sensors like temperature, humidity, and air quality sensors, there's potential to develop more advanced and precise sensors that can detect minute changes in the hydel power environment, leading to even more efficient monitoring and maintenance.
- **Predictive Maintenance**: Utilising the data from IoT devices to predict when parts of the hydel power plant might fail or require maintenance, thereby reducing downtime and increasing efficiency.
- **Energy Storage and Distribution**: Researching how IoT can aid in the better storage of energy generated from hydel power and its efficient distribution, especially during peak demand times.
- **Integration with Other Renewable Sources**: Exploring how hydel power, monitored and managed by IoT, can be integrated seamlessly with other renewable energy sources like solar and wind to create a more robust and resilient energy grid.
- **Enhanced Security Protocols**: As the integration of IoT devices increases, so does the potential threat from cyber-attacks. Future research can delve into creating more secure systems and protocols to protect the data and the infrastructure.

5 Knowledge Gaps

The exploration of the Internet of Things in the hydel energy sector has certainly paved the way for innovative solutions and applications. However, there remain certain knowledge gaps that need addressing:

- **Standardisation**: With a myriad of IoT devices and sensors available, there's a lack of standardisation in terms of technology and protocols, which can hinder seamless integration.
- **Data Overload**: While IoT devices generate a wealth of data, the challenge lies in effectively processing and utilising this data for actionable insights.
- **Interoperability**: The ability of different IoT systems and devices to work cohesively together remains a challenge, especially when integrating devices from different manufacturers.
- **Environmental Impact**: The environmental footprint of producing, deploying, and disposing of IoT devices in the hydel energy sector is not yet fully understood.
- **Economic Viability**: While the potential benefits of IoT in hydel energy are evident, the economic implications, both in terms of investment and returns, need further exploration.

In conclusion, the integration of the Internet of Things in the hydel energy sector offers promising avenues for enhancing efficiency, reliability, and sustainability. However, to fully realise its potential, it's imperative to address the existing knowledge gaps and focus on areas of future research.

6 Conclusion

The transformative potential of the Internet of Things (IoT) in reshaping the hydel energy sector is undeniable. As we reflect upon the insights presented in this review article, several key findings emerge that underscore the profound impact of IoT on hydel energy systems:

- **Enhanced Efficiency**: IoT's integration into hydel energy systems has led to significant improvements in operational efficiency. By continuously monitoring and analysing data from various sensors, it's now possible to optimise energy production and distribution in real-time.
- **Seamless Integration**: The role of IoT in renewable grids, especially in hydel power, has facilitated the seamless integration of renewable energy sources. This not only stabilises the energy grid but also ensures a consistent energy supply, even when renewable outputs fluctuate.
- **Predictive Capabilities**: The data-driven nature of IoT allows for predictive maintenance and monitoring. This proactive approach helps in early detection of potential issues, reducing downtimes, and ensuring the longevity of hydel power infrastructure.
- **Holistic Monitoring**: From temperature to humidity and even air quality, the diverse range of sensors employed in hydel power plants provides a comprehensive overview of the plant's health and performance, leading to informed decision-making.
- **Security and Privacy Concerns**: While IoT brings numerous advantages to the table, it also raises concerns about data privacy and security. The review highlights the need for robust security protocols to safeguard critical infrastructure and sensitive data.
- **Economic and Environmental Implications**: The integration of IoT in the hydel energy sector has economic implications, with potential for cost savings in maintenance and operations. Moreover, by optimising energy production and consumption, IoT also contributes to reducing the environmental footprint of energy generation.

In light of these findings, it's evident that the integration of IoT within the hydel energy sector is not just a technological advancement but a paradigm shift towards sustainable and efficient energy systems. As highlighted in the abstract, the fusion of modern technology with traditional energy systems promises a future where energy consumption is not only efficient but also environmentally responsible. The insights from this review serve as a testament to the transformative power of IoT in steering the hydel energy sector towards a sustainable future.

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