WHITE PAPER

INDUSTRIAL IOT IS ACCELERATING THE DEPLOYMENT OF HYDROPOWER TO ACHIEVE NET ZERO

This paper aims to present the evolution of hydropower generation over the next two decades. It provides insights on the role of modern technology, specifically Industrial IoT and Industry 4.0 technologies, the tangible benefits they can deliver by improving efficiency, reducing costs and enhancing safety across the engineering, build, operate, maintain life cycle stages in hydropower plants. We recognize the major role that hydropower will play in the power system, especially when we add large-scale variable generation in the network to meet net zero emission target. Variable generation in the system has implications for the reliability and stability of the power system. Hydropower plants, including pumped storage, significantly provide network balancing power and improve network reliability, stability and safety.

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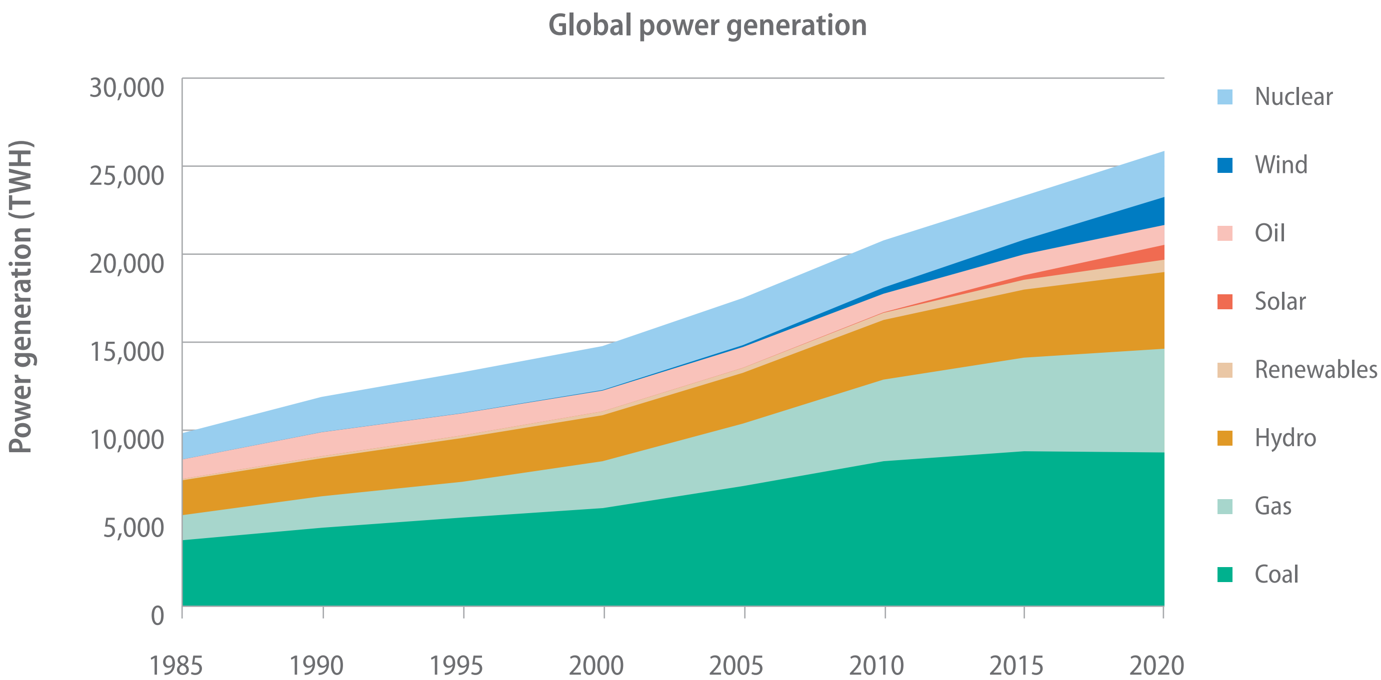
Status of hydel power plants

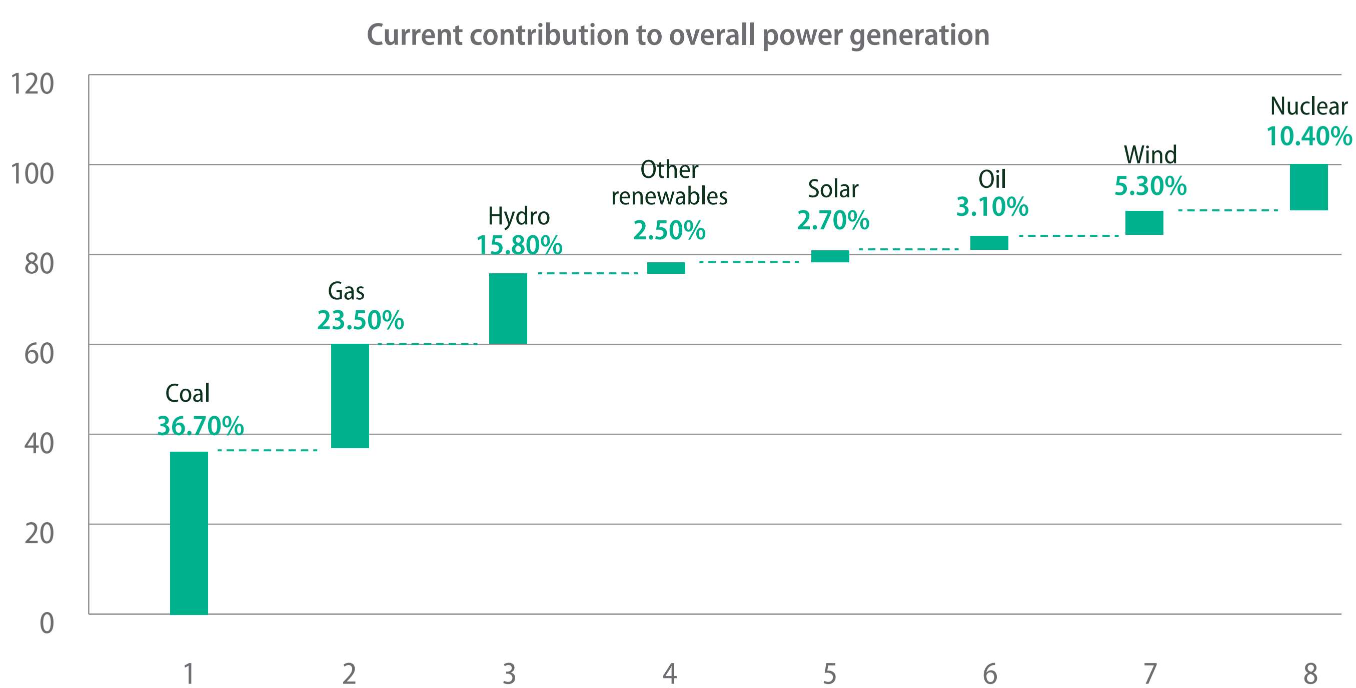
Research[1] shows that the current total electricity generation was around 26000TWH in 2020 (Fig 1).

Fig 1. Global power generation (2020)



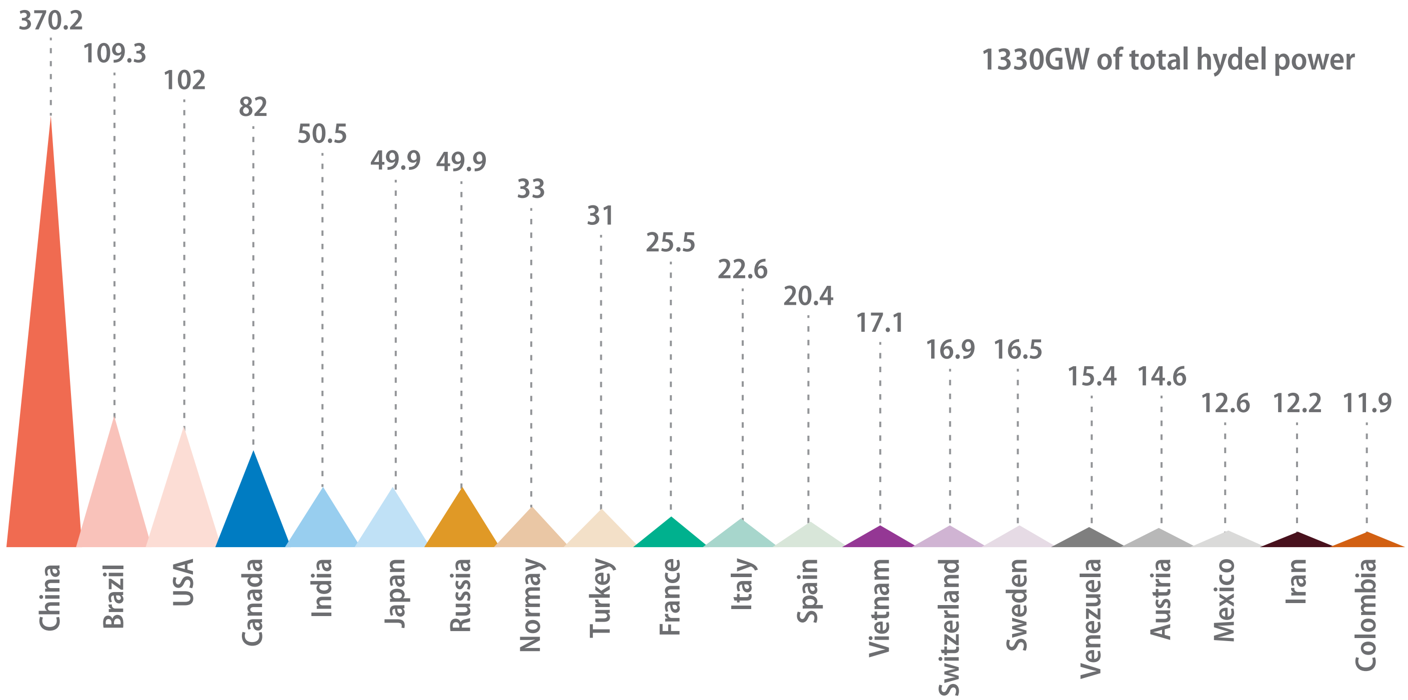
Hydropower generation contributes 15.8% (Fig 2) to overall generation and is the third largest source for global electricity requirements, behind coal and gas.

Fig 2. Percentage contribution of different electricity sources[3]



The top five countries, China, Brazil, USA, Canada and India, account for nearly 60% (Fig 3) of the global hydel power generation, while China alone generates 30%.

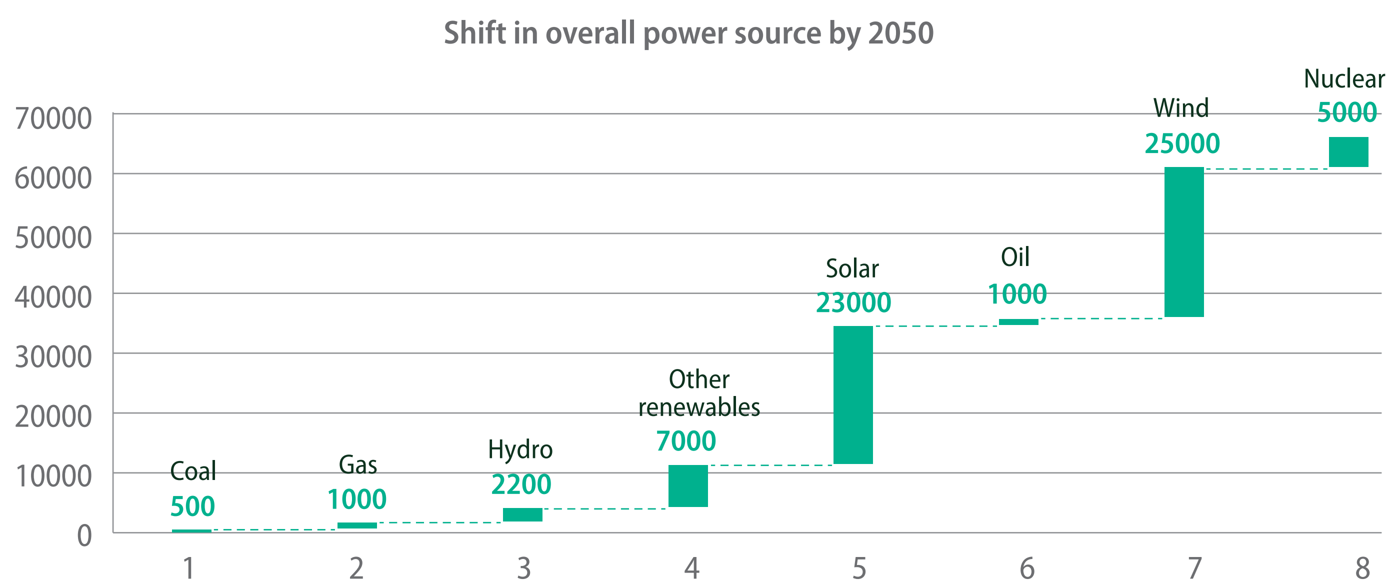
Fig 3. Hydropower - country wise generation[2]



Importance of hydropower to reach net zero emission by 2050

As the world pursues an ambitious target to reduce carbon emission and limit the global warming temperature increase to 1.5-2.0 deg C by 2050, a clean source of electricity is a critical success factor. Currently, the world is focusing on maximizing electricity generation from renewables instead of traditional fossil fuels. There are aggressive plans to accelerate the installed capacity of solar and wind energy from the current 10%+ to 60%+ of global power generation (Fig 4). In addition, significant research is underway to find alternate sources of clean electricity.

Fig 4. Power source distribution by 2050[3]



While hydropower plants are expected to drop to 5th position in the overall contribution to the global electricity generation, still an additional capacity of 850 GW4 of hydropower is expected to be added in the next couple of decades to meet increased demand and contribute to the Net Zero target. There is yet another dimension that makes the dependency on hydropower plants very prominent, the problem of the intermittences caused by renewables. As the number of renewable plants increases, power fluctuations on the grid due to intermittences caused by climatic variations becomes a high possibility. Hydropower plants can be an effective alternative to support intermittencies and load fluctuations. Hence, accelerated development and efficient management of hydropower plant becomes an important requirement to complement the surge of Solar and Wind Generation plants.

Challenges faced during development and operation of hydropower plants

Some key challenges during setting up a hydropower plant include –

1) Difficult terrain and remote location – Most hydropower plants are in mountainous terrains which are inaccessible and need creation of enabling infrastructure. These terrains are unpredictable and pose challenges in terms of accessibility and safety to human lives due to landslides and soil erosion.
2) Skill of resources - Mobilizing skilled resources and good program managers with relevant experience.
3) Employee safety - Tracking employees and ensuring employee safety during the commissioning of the plant.
4) Duration of the project and impact on financials – Hydropower plant development usually takes a long time for development leading to high cash outflow before they become operational.
5) Project financing – Changing scope, requirements, improvisations, and market dynamics.
6) Engineering – Geological and Geotechnical challenges.

In addition, hydropower plants face different sets of challenges during operations that include –

1) Asset management – Managing equipment availability and efficiency as the equipment starts aging
2) Reservoir management – Managing water flow from reservoirs
3) Sediment management – Impact of mud and slurry on generation assets

4) Weather – Monitoring of weather for heavy rains and threat of floods
5) Load management – Varying load demands and ability to plan generation to varying load needs
6) Skills management – Trained resources to operate and maintain the plant.

The role of technology in construction and monitoring of hydropower projects during development

Advanced technologies like IoT, AI and image analytics have started playing an impactful role in the design, build and operations of hydropower plants. They can play an enabling role in tackling challenges and accelerating the development of these plants. In this section we look at some of the advanced technologies that can help address some of the major challenges:

Drone and imaging

As drone and thermal imaging technologies mature and become more affordable, the major challenge of understanding the terrain and monitoring project progress can be addressed effectively. Drones can be used for the initial aerial surveys as well as to monitor the hydropower plant construction progress. Likewise, thermal imaging can provide good insights into the terrain condition to assess any unforeseen land or mudslides which may hamper the project and threaten human safety.

Drones can capture every minute detail of the plant construction and help design engineers analyze images and monitor the project progress more accurately. This technology plays a key role in eliminating any design-to-build conversion related defects and ensuring the project progresses at a good pace by eliminating rework or redesign.

The drone should be able to fly over the construction site and capture high-resolution images and thermal map of the construction work in progress. These images are transmitted to the ground station, where analysts process and analyze the data (Fig 5). Design engineers can then review the reports generated by analysts to track the progress.

Fig 5. Drone and image analysis architecture

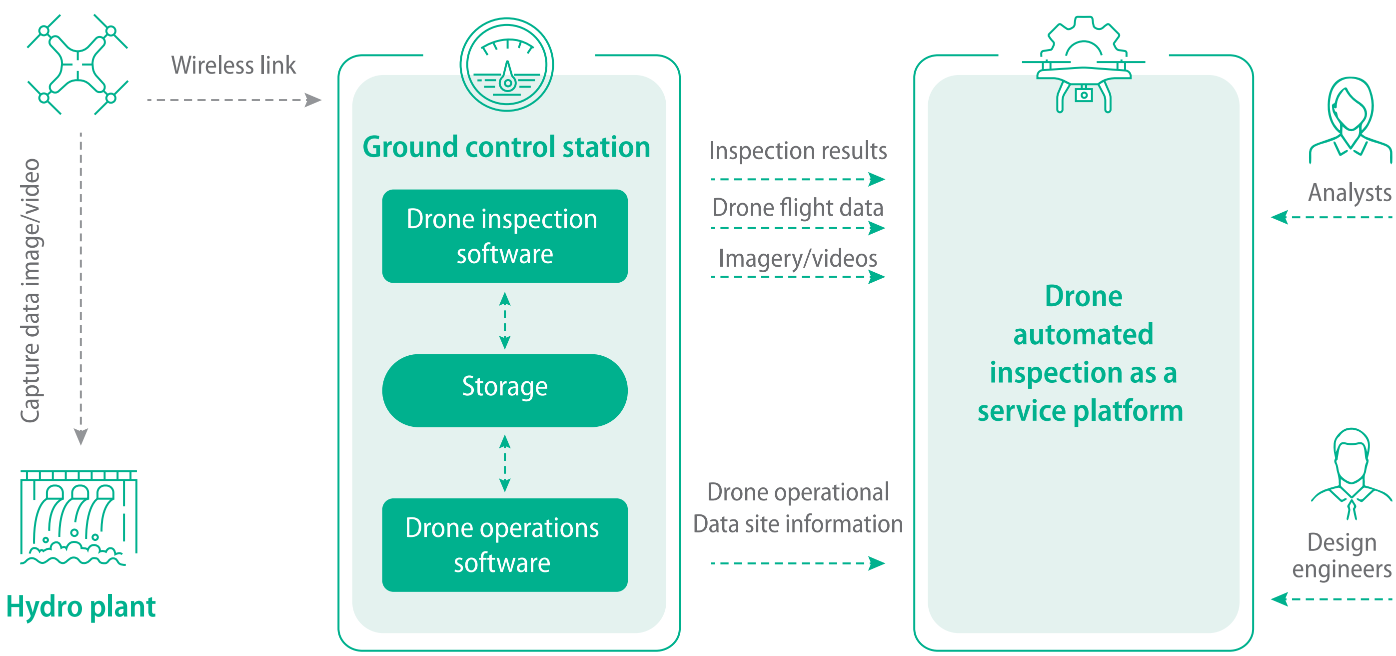
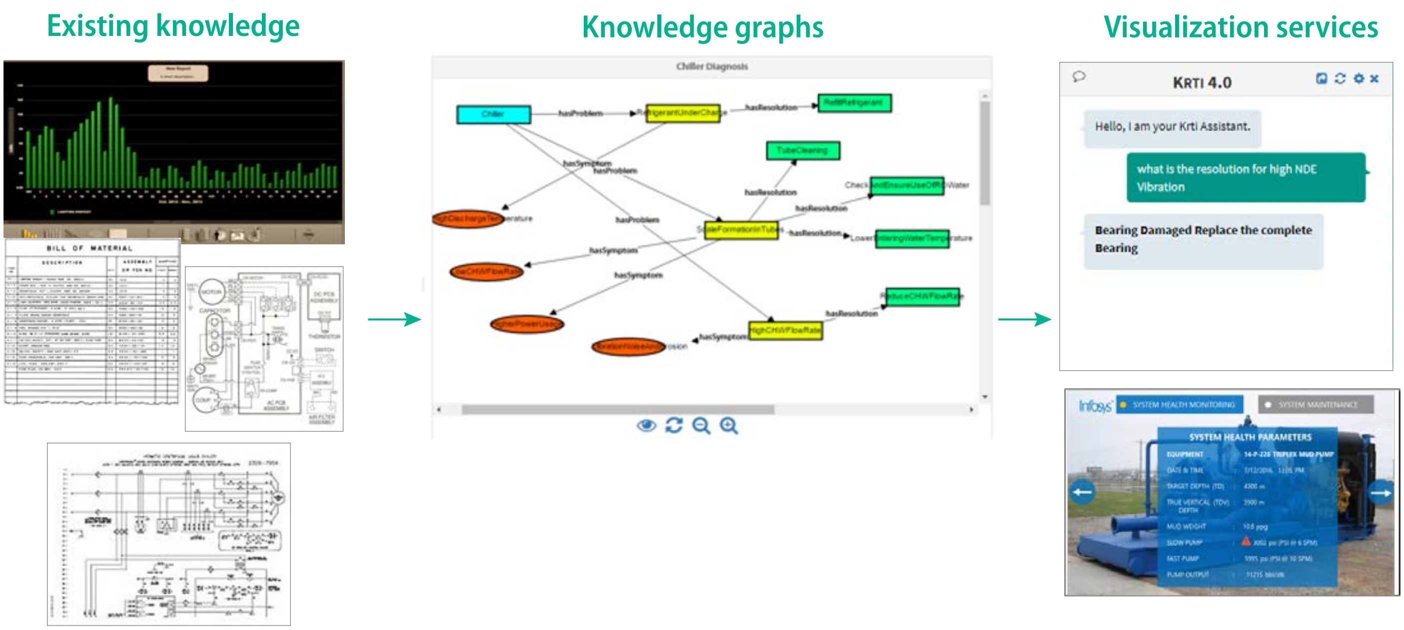


Fig 6. Knowledge platform and augmented reality



Knowledge platform and augmented/virtual reality

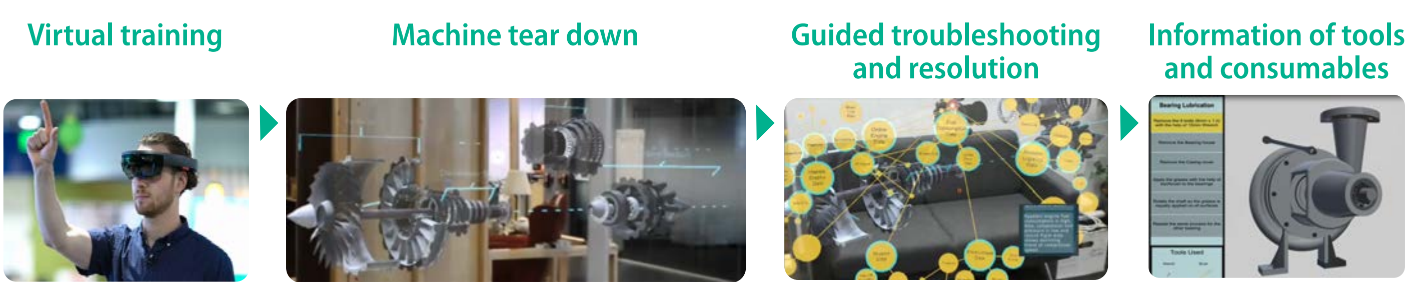
As global energy generation enterprises plan to develop 850+ GW of hydropower to meet the net zero target, one of the key challenges is harnessing the existing knowledge and accelerating skill development for the different people working towards this target. Modern day technology enables converting the existing knowledge into ontologies or knowledge graphs that can be dynamically referenced via chatbot or augmented reality views to help different stakeholders gain quick references to their design requirements (Fig 6).

Multiple such platforms at varying maturity levels can help develop the knowledge graph and customize it to different requirements. Some well-known ones include SiSense, IBM, Ontotext and Infosys Knowledge Platform.

Virtual reality (VR) solutions can enhance the skills of different technicians and plant workers by providing the requisite amount of information and practice needed to carry out their day-to-day activities and prepare for any emergencies and abnormal situations. The VR environment helps to simulate different scenarios that a person might encounter during the hydro plant development . It can feed information from the Knowledge Platform to create scenarios and guide the person to undergo different training programs (Fig.7).

Some well-known VR devices include Microsoft HoloLens, Facebook Oculus and Samsung Gear VR.

Fig 7. Virtual training using virtual reality and knowledge platform



GPS tracking and image recognition

The efficiency and capacity of hydropower plants are tied to the terrain in which they are set up. This becomes a primary obstacle in getting good resources and making speedy progress in developing hydro plants. The projects have failed to attract good talent due to the risks involved and lives lost in the project historically. In the past, tracking a human being on the ground during construction activity or weather abnormality was challenging, leading to loss of lives and fatal accidents due to the non-availability of timely help.

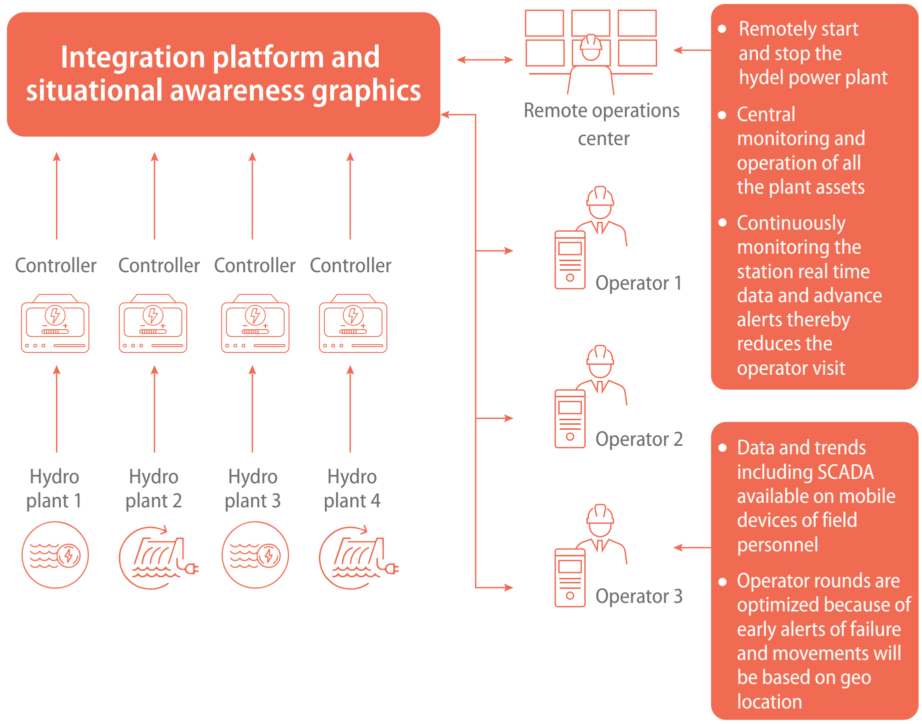
IoT has now enabled better tracking and monitoring of humans on the ground to ensure safety. During an emergency, help is mobilized quickly to lower fatality and restore a safer environment. Workers are now provided with tracking bands as wearables with emergency buttons. Organizations can set up command centers to monitor employees on the ground (Fig.8). In addition, they can set up temporary cameras to track people's movements. Further, image analysts in the command center can monitor people and any abnormal movement of animals or reptiles and loose soil formation that could cause accidents.

Fig 8. Image based object detection

The role of Industrial IoT hydropower in addressing the operational challenges

Industrial IoT has brought many integration capabilities between systems and devices. The vertical and horizontal integration capabilities have improved across various components of the ISA 95 stack layers. It helps in better information management and quicker decision making. Several AI/ML solutions which have started maturing, help with analytics and predictive capabilities to make operations more efficient. With the advent of 5G and a more reliable and low latency network backbone, a major part of the operations in future hydro plants can move from local to centralized remote operations. This section looks at some solutions that will shape the future of hydropower plant operations and maintenance.

Fig 9. Remote operations center



Remote Operations Center

We expect this to be the future mode of hydel power plant operations. Organizations are expanding the capacity and the number of generation units; this, combined with the lack of skilled resources to manage operations and maintenance, makes a strong case for a Remote Operations Center. The number of operations in a hydropower plant is limited to very few manual interventions required every day. As a result, organizations now can optimize resource utilization and overcome the lack of skilled resources challenge.

The Remote Operations Centre integrates the hydel power plant's PLC controls, turbine control, generator protection, compressor controls and switch gear controls. It shares the information with the centralized monitoring and control center over a 5G network. Operators are trained to monitor multiple plants using situational awareness-based graphics so that they need to react only to abnormalities. Each abnormality is defined by an SLA, and hence they have clear guidance on the reaction time and agility of response required. There is a skeleton staff in the plant to handle emergencies. As a result, human safety related risks are mitigated by moving people away from the risky environment.

Analytics and predictability with ML and AI[5]

Key challenges related to asset management, sediment management, reservoir management, load management and weather forecasting can be addressed using multiple AI and ML techniques.[1]

Machine Learning can be harnessed to understand the patterns of failures and reasons behind them for critical assets like turbines, generators, transformers, GIS and gate valves using the historical data stored either in traditional plant historian or time series data store in the modern cloud platform like Azure Timeseries Insights or AWS Timestream. For example, the machine learning modules can learn from different anomalies developed during the operations. It can look at patterns from condition monitoring signals like vibration, temperature, partial discharge and relate them with the behavior of process parameters like flow and pressure. At the same time, it can examine the impact on overall power generation (active power, reactive power, power factor) to identify probable failures. As a result, the models deployed can predict potential failures with a high degree of accuracy. This helps the organizations to plan effectively.

a) Power generation based on water inflow, water level and demand

b) Spares parts management based on historical consumption for carrying out repairs

c) Mobilizing the workforce to carry out repairs.

Digitalization of a few main hydropower generation units in India has improved production efficiency by 1% through better flow distribution among the different turbine units. In addition, a better inflow forecast reduced the water spill increasing the annual generation by 11%.

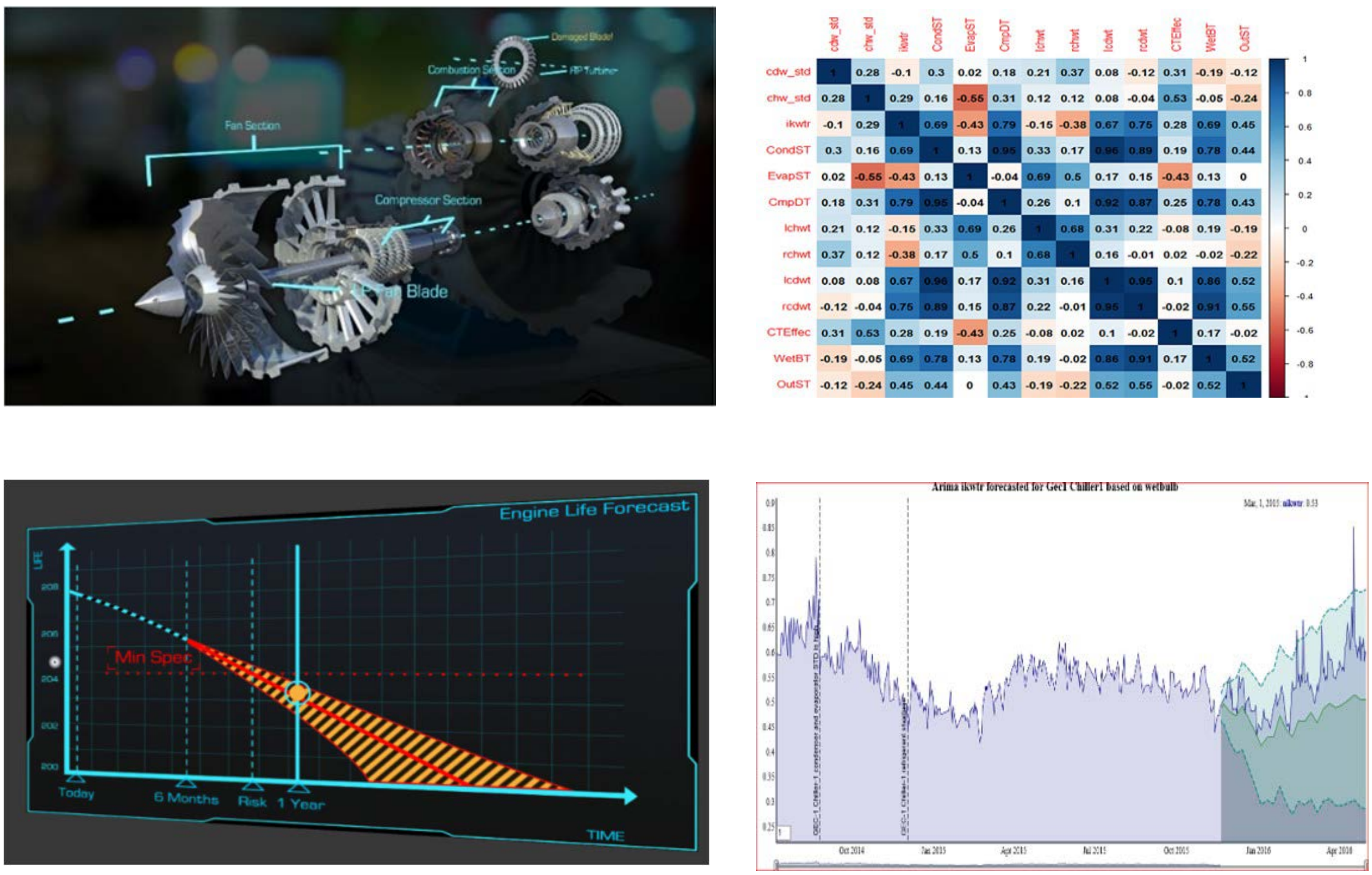
Some implementation examples that have helped hydro plants to be more efficient include:

a) Continuous monitoring of the flow of water, pressure and thereby monitoring the health of penstock and other pressurized pipes to avoid major disruption/failure.

b) A key part of the plant is the turbine, and its efficiency drives the hydropower plant efficiency. When the water leakage from the turbine increases beyond the permissible limit, there is a need to monitor and proactively detect it for repair/replacement.

The ability to predict failures would help reduce the number of unplanned shutdowns and increase the availability of assets to run the power plant resulting in a higher generation.

Fig 10. Prediction of failure using anomaly detection



On similar lines, sediment and reservoir management can also be planned better using historical data analysis and patterns of information. These can provide triggers for sediment removal and the reservoir to retain live storage of water. As a result, the plant can meet demands for power generation.

Integration with weather APIs and usage of weather details to be able to predict in advance events such as water availability for generation, flood condition and cloudburst, as well as plan for power storage requirements. This prediction also helps flood routing and ensure the safety of human, material and machine.

Load demand forecast can also be done using advanced analytics. Historical data can be analyzed to understand the consumption patterns and predict future requirements depending on various factors such as types of consumers, seasonal variations, and variations due to climatic changes or festivities.

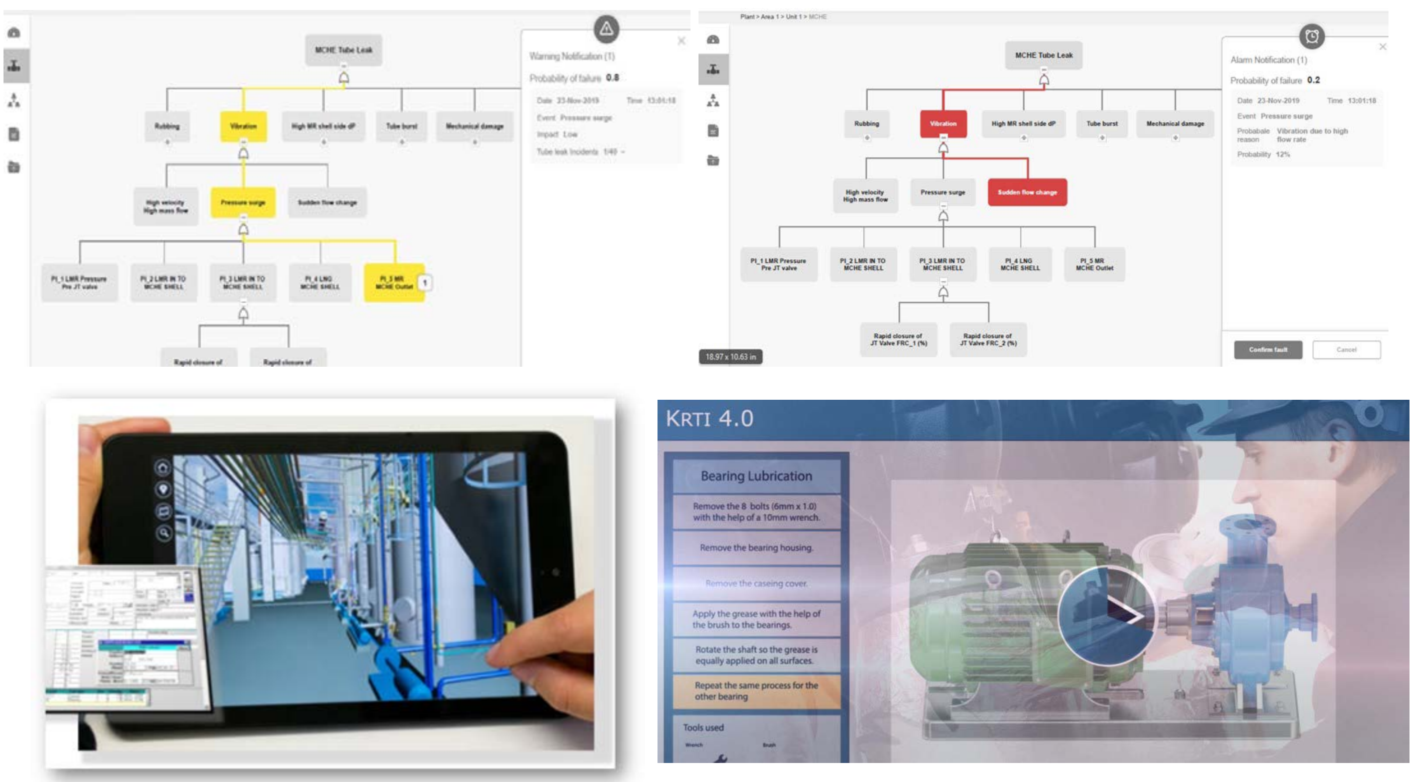
Smart fault tree, knowledge platform and smart glasses

Smart fault tree driven by ML and AI models in the backend can provide advanced prognosis and detailed insights into faults along with the root cause for the issue. This helps reduce the dependency on skilled resources in the plant to troubleshoot, identify the root cause and plan for resolution. This solution powered with knowledge platform in the backend can provide detailed resolution instructions to technicians on the field to carry out repairs or maintenance. The plant technicians can also use smart glasses like Google Glass or RealWear to communicate the current plant situation to a central pool of experts to seek guidance to fix issues. These technology advancements will boost plant availability, significantly increase mean time between failures (MTBF) and reduce mean time to recovery (MTTR).

Digital twins

The revolution that SCADA systems brought about in the late 1980s and early 1990s changed how industrial plants operated. We expect digital twins to provide a similar transformation shortly. They would be able to integrate Engineering, Operations and Information Technologies and manage every individual asset in the hydropower plant from design to operation and to retirement.

Fig 11. Fault tree based root cause analysis and resolution



Digital twins would have capabilities to integrate the simulation engine, analytics engine, drone systems and enterprise applications to provide end-to-end management. In addition, it would have multiple user interface services, including 3D visualization and augmented views. These services provide users with different depths of information depending on the perspective they are trying to derive and interpret during different life cycle stages of the hydro plant.

Fig. 13 shows the reference architecture of a digital twin that can be operationalized for multiple hydropower plants together.

Digital twins are trending to become the next generation operation and control solution. Hydro plants are likely to benefit most after mining and oil extraction units. Digital twins would allow operators to make a more informed decision. Under one visual umbrella, they would get real-time, analytical and design views. The digital twin would also allow operators to run different simulation scenarios and make decisions based on parameters like weather, sediment and demand.

Fig12. Digital twin utilization across the life cycle of a hydro plant

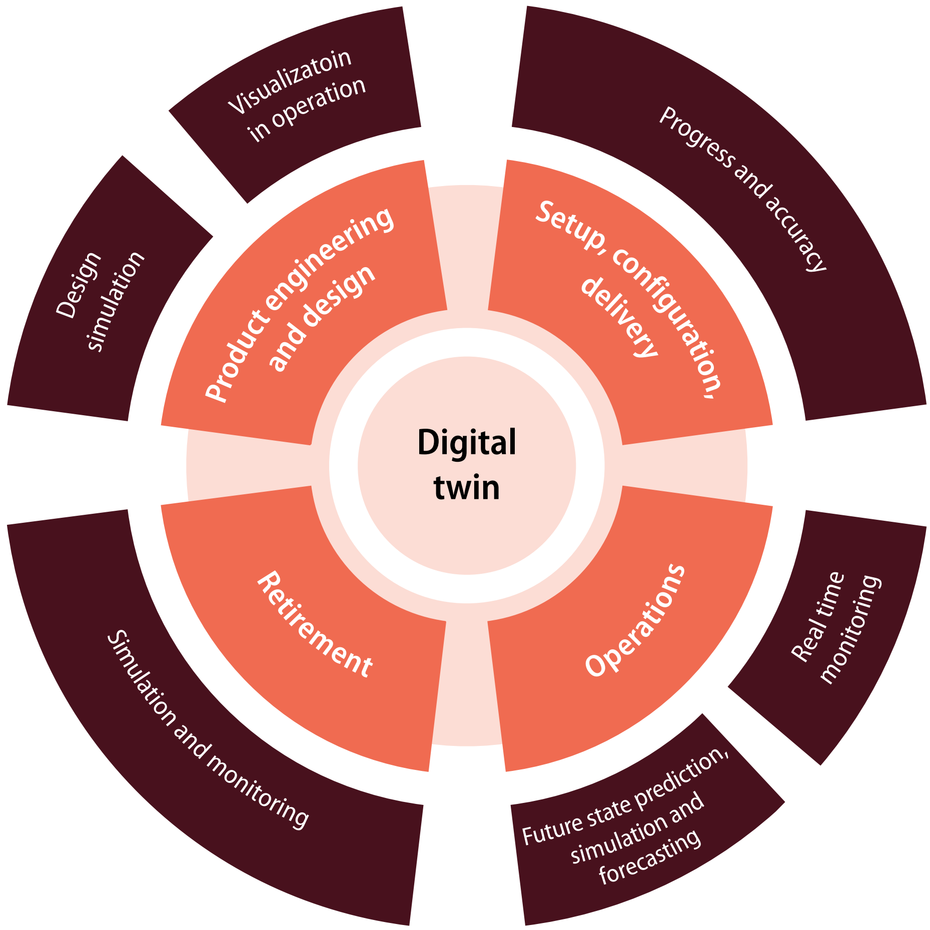
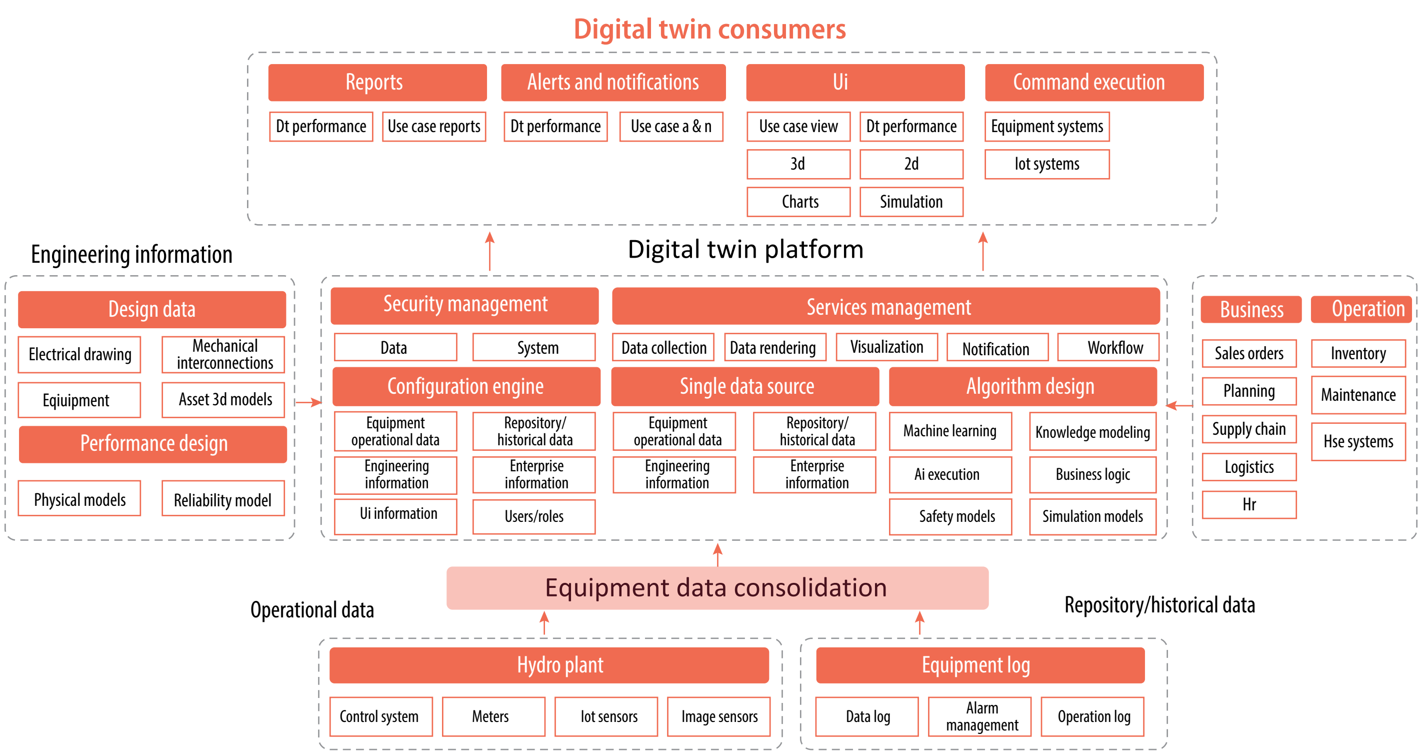


Fig 13. Digital twin reference architecture



Conclusion

As the target is to reach net zero emission by 2050, steam, hydropower plants will play a significant role in reaching the target. The challenges of operating a hydropower plant are not related to the complexity of design or operations. Instead, they are related to executing and setting up the plant in difficult terrain and getting skilled resources to operate in remote locations. Technology can play a key role in overcoming these challenges. This paper presents some of the key technology solutions that can help accelerate setting up of the hydropower plants and operate them with minimal people stationed inside the plant.

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