Accelerating renewable energy generation over industry 4.0

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ABSTRACT

The "Industry 4.0" (the fourth industrial revolution) is recognized as a new industrial step in which horizontal and vertical manufacturing progress combination and product connectivity may supply benefit producers to achieve higher technical achievement. However, especially in developing countries; limited information is known about how industries could meet the implementation possibilities of the Industry 4.0 associated technologies to achieve industrial production and performance.

This paper briefly reviews and describes industry 4.0 and environment for modernization. The paper also discusses what are the current objections met by companies especially energy generator companies according to hydropower plant operators' experiments. The paper offers an approach from strategic planning to operational level for the implementation of industry 4.0 for all manufacturers especially the energy sector. Also new opportunities, applications and scenarios examined by introducing the technologies and tools for Industry 4.0. Finally, it referred a conclusion and brief look of the future work.

1. Introduction

The Industrial Revolution is one of the most famed and revered milestones in human history [1]. They are mostly accompanied not only by technical and scientific innovations but also by the essential aspects involved in the Industrial Revolution were technological, cultural and socioeconomic [2].

In order to explicate the theory and perception of technological revolution, initially, we need to define the notion of technology. It represents a set of technological knowledge about how to conceive, produce, use and even commercialize goods or services or their elements; or in the accomplishment of objectives, such as scientific investigation, as well as any possible aggregation of these operations [2]. Industrial Revolutions, basically, is a period in which machines bring meaningful developments to the people's way of life particularly in the manufacturing environment [3]. As history provides [4].

The first Industrial Revolution launched in the 18th century when agricultural communities became more modern, technical and urban. The first mechanical revolution occurred in the middle of the 19th century and was accompanied by a process of economic growth as a result of the industrialization of North America and Europe [2,5].

Industry 2.0 also known as the Technological Revolution began from the end of the nineteenth century continued up to the 1980s [6]. It was the period when industrial products started to increase both in variety and volume. Major technological innovations included the transcontinental railroad, the cotton gin, electricity, mechanical devices, cars, and other inventions permanently changed society. Industry 2.0 products are still effective today [7].

Industry 3.0 began in the 1980s and also known as the Digital Revolution. It is characterized by technological innovations such as the change from analog to digital, which had considerable influence, especially on the electronics industry [8]. By this revolution; production of automation had increased, people empowered to "higher-level jobs" – i.e. programming and automotive industry had use of robotics. The demand for goods during Industry 3.0 increased to three dimensions which are volume, variety and delivery time [7].

Organizations that want to be ahead of the global competition in the world of the future have to achieve with smart robots that will work in production and distribution processes, research and development, sales marketing and management processes to be used with artificial intelligence systems. Nowadays the world is witnessing the 4th technological

revolution; namely Industry 4.0. Fig. 1 shows main transformation areas in the world.
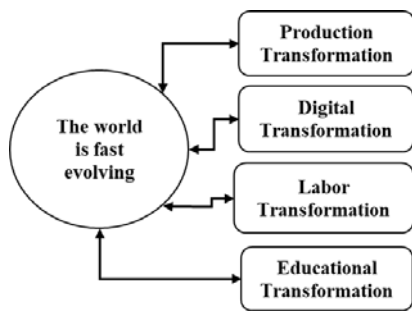
Figure 1. *Fast-evolving world*

Many different definitions exist for Industry 4.0 by companies and various groups according to their wishes and understanding. The main idea of industry 4.0 demonstrates how complex production processes can be optimized using new Technologies. A formal definition of industry 4.0 is defined in [9] as follows: It is understood as a new industrial stage with technology innovations such as manufacturing operations systems and information and communication technologies (ICT) – especially rapid developments in the fields of the Internet of Things (IoT), Big Data, robotics, blockchain technology, sensors, artificial intelligence, augmented reality and rapid prototyping technologies. We define Industry 4.0 as a revolution enabled by the application of advanced technologies (like IT) at the manufacturing level to bring new values and services for customers and the organization itself. Many aspects of Industry 4.0 are undefined, undiscovered and uncertain, such as the demand dimensions of customers and the future product architecture of electricity generation and electric vehicles [7]. If we Google "fourth Industrial Revolution," that's somewhat synonymous with industry 4.0. The idea is after the digital age, the computer age, what we've got now is a collision of the digital and physical ages. We have Internet of Things devices. We have data analytics, machine learning, artificial intelligence, and all of those are changing the relationship, we have to each other and to the machines around us, both the physical machines and the ethereal machines, like cloud computing systems. So industry 4.0 is one in which standard manufacturing, standard production of goods is being superseded by the idea that you can use digital technologies to change the whole dynamics and calculus of manufacturing. And 3D printing is actually a very good example of that. The industrial revolutions are depicted in Fig 2.
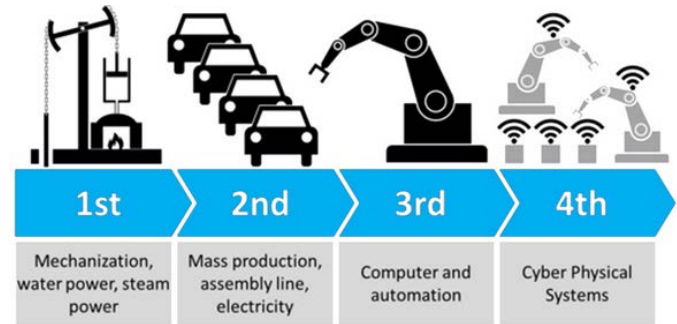
Figure 2. *Stages of industrial revolution [10]*

2. Importance of industry 4.0

While 4th technological revolution has been developing at a dizzying pace in recent years, the public is divided into 'worries' and 'hopefuls'. So, what kind of future will artificial intelligence offer us? How does the world use these technologies? The world and Turkey, at which point the Industry 4.0 fields? The most curious question for academics, professionals, and entrepreneurs is: whether the machines can think? The British mathematician Alan Turing, who introduced this question for the first time in 1650, had not imagined the point reached today [11].

But today computers can beat the chess champion. Or in the quiz, it can make a slam to its competitors. Thousands of years of the strategy game can defeat the champion in "Go". They can even quickly move and open the doors. But sometimes they can make mistakes. Just like the "Robot Mini Ada", which had an accident in the past days in Konya City, Turkey.

Industry 4.0 has been developing at a swift pace in recent years. Because artificial intelligence is fed by data, and there is much more data than before. It is made by imitating human movements and behaviors by software and algorithms. When it comes to this revolution, many people think of robots that we are familiar with from movies. But in fact, we use them in almost every aspect of our daily lives.

Robotics and automation systems provide the muscle for Industry 4.0, cameras and other sensors provide the senses, and connectivity and data are its central nervous system. But in the background, the real brains of this industrial revolution is Artificial Intelligence [12, 13]. When we use each search engine, we also benefit from artificial intelligence. Or we use artificial intelligence again when using virtual assistants on smartphones. For example, artificial intelligence algorithms for diagnosing disease from medical images work very well.

For example, this artificial intelligence technology used in the IOWA university clinic in the United States can identify and prevent the corals from sugar diseases [14]. This area is becoming increasingly popular, and the countries are interested in it [15].

Countries that make the most investment in artificial intelligence in the world at the beginning of the United States and China is coming [16]. The same two countries lead the academic publications [17].

Many countries have announced their national artificial intelligence strategies. The first was explaining Canada and followed by China [18]. For example, China said it aimed to be the world's largest artificial intelligence force by 2030 [19]. It focuses on a number of issues, most notably the funds allocated to artificial intelligence studies. After that, the important thing is that people who develop artificial intelligence technologies.

In Turkey, many institutions producing national artificial intelligence projects. One of them is Turkcell [20]. The company is preparing to market the first virtual assistant in Turkey. There are also artificial intelligence entrepreneurs. Sercan Esen, a 28-year-old from the private sector, who spent 4 years working on his own project, is one of them. The two young entrepreneurs developed the award-winning project namely "intenseye" in Istanbul Technical University.

Performing a first time in Turkey with this artificial intelligence video recording applications, gender and emotion analysis can be done. It can also use magazines to do customer analysis. Or in the contact and transportation points for smart cities, airports, metros can use this solution. For example, in the production facilities, businesses can analyze the emotions of their employees. When working with a tool; they understand how intense and stressful you are and can intervene and prevent accidents. Civil-society organizations are also doing all works for widespread use of artificial intelligence in Turkey. "Deep Learning Turkey" is one of them, bringing together professionals, academics and entrepreneurs. They have a lot of members in the community, and they share information with each other, and they do projects together. In summary; Turkey is closely following the work of artificial intelligence. So what's the next step?

In fact, in general, like every developing country, Turkey also needs an artificial intelligence strategy as a nation in order for these studies to come together and to provide them with more benefits.

What kind of future will artificial intelligence offer us? There is no doubt that it will enter many areas of our lives. How can we do many things that exist in our daily lives when electricity is found, how we can do it? That's exactly what countries need to do right now. How can we do even the most complex things in our daily life with artificial intelligence? Applying artificial intelligence to everyday life. Machines can be part of our daily life. According to some, there is nothing to fear, but the number of those who are concerned is not small. For example, in the state of Arizona, on March 13, 2018, the fact that Uber's driverless vehicle caused the death of a pedestrian opened the door to a new debate [21]. Nowadays the scenarios that robots take control are also very popular. There are different views about how artificial intelligence will transform the world.

-The development of artificial intelligence can lead to the end of humanity. (Stephen Hawking) [22,23]

-We can use artificial intelligence to create heaven or hell. That still depends on us. (Yuval Noah Harari) [24]

-There will be very, very little work that Robots cannot do better than people. (Elon Musk) [25]

According to the US-based Mckinsey consulting firm, by 2030 robots could leave 800 million unemployed. Automatic cash registers, driverless cars, robot security guards are already starting to enter our lives [26].

We be aware or not; we have an industrial revolution. But this does not mean that systems are created to completely replace people. The aim should not create systems that replace human beings with artificial intelligence algorithms, but create the capabilities of people, the characteristics of people and the systems that develop and integrate. Therefore, it shouldn't be imagined where the environments of only the people work, or the machines work. But we imagine the systems where people and machines can work together, people work where people are good, machine can be used where the machine is good.

What will the manufacturing of tomorrow look like? There is no clear answer to how Industry 4.0 will transform the world. But it is obvious that the transformation has already begun and the energy sector has the chance to be part of it and will be on our agenda for many years. This is not going to be the same likes before. There's going to be a huge change. It's not about the steam that feeds our plants in the first revolution, or dominant mass-production model in the second, or even computerized systems come out of the third revolution that we live today. The basic principle of Industry 4.0 is about automated connectivity which manufacturers worldwide are connecting their machines to the cloud and progressing their owned industrial Internet of Things. It's an opportunity to radically change the way industry impacts the needs of individuals and societies. The advancement of Industry 4.0 will be guided by an intelligent, interdependent and widespread environment, as innovations in production processes and systems are led by earlier industrial revolutions. Those left behind the revolution will feel it keenly for the jobs are today might be dramatically different in the not too distant future. There is still a space for leaders of this new revolution to emerge, but the race has already started. [27]

Industrial parts are becoming smaller. Products get to market with less waste, faster, and on-time. Even the most manual processes are turning towards automation. Innovations in deep learning, machine vision, fuzzy logic, and robotics are

revolutionizing production lines and supply chains. The machines now produce vast amounts of Big Data, accessible via the cloud. As the information and machines, they produce become connected, new cyber-physical systems will glint a modern-day Industrial Revolution. This is Industry 4.0. In the Industry Revolution, machines become smarter and learn from their environments and take corrective actions to optimize production. These machines work without regard to a central controller, collaborating and communicating with other devices. Industry 4.0 facilities produce new organizational intelligence, which expands across facilities. The result: nothing short of total transformation of production lines and business performance. Machine vision will be at the mainline of this new manufacturing paradigm. [28]

The power network is also changing. With the increase of renewable energy generation technologies and drive to make a better demand response, the grid's current environment must change to realize the promise of the IoT.

3. Industry 4.0 for energy generation

To meet the need for greater flexibility in hydraulic systems and to maximize overall equipment efficiency, production processes must automatically adapt to changing demand. This requires smart devices that communicate with each other in real-time and a controller platform that serves as a hub for seamless providing two-way communication from the corporate network up to the actuators. Today, important steps have been taken on Industry 4.0 theory in hydraulic applications. The most important of these is to connect the hydraulic equipment to the digital control electronics to process the steps in the software. In addition, all the features of fluid technology have been stored in the form of algorithms in the software.

There are 5 important points for the application of Industry 4.0 in power systems. These are:

- Compatibility of power system components for the current structure of Industry 4.0,
- Easy control of the structure of the power plant and consequently to increase the efficiency of the system,
- It can be controlled from a single point, so that operating costs can be reduced,
- Easy monitoring of plant equipment,
- producing alternative solutions with advanced control applications.

Today's many Central Station controlled power grids operate on update cycles that are as long as 15 minutes. Approximately every 15-minute outage information is updated, and Central Station estimates the power and sets its generators to meet the load. Unlike conventional power from fossil fuels, renewable power sources such as wind turbines or hydropower plant a predictable output at the same time. Fast loads like plugging in electric cars are also hard to predict. If the grid drops below the needed power, it can fail. So; to ensure sufficient power grid operators maintain extra power plant reserves to compensate for these fluctuations. That keeps the lights on, but it wastes fossil fuels. It means the renewables are not lowering the carbon footprint as much as they should. To deliver on the promise of renewable energy, the Industrial Internet Consortium (IIC) started a new initiative named the communication and control testbed for microgrid applications to enable the efficient use of renewable energy resources at a large scale. This is an ambitious goal. But when the expertise and the technology come together, the dream can become a reality [29]. The industrial Internet of things provides a disruptive technology that will change the way the grid operates. Three members of the IIC are lending their expertise to the microgrid communication and control testbed Project. Real-time Innovations (RTI) is providing real-time data bus software. National Instruments is providing the intelligent nodes for edge control in analytics. Cisco is providing network equipment and security expertise. The open FMB project at the smart grid interoperability panel is defining communications data model and services standards. Duke Energy Southern California Edison and CPS Energy will take the architecture through performance and security testing to prepare it for real-world challenges. The goal of the new initiative is to prove the viability of real-time communications and control framework which combines distributed edge located processing and control applications with intelligent analytics. A real-time secure connectivity framework enables machine-to-machine, machine to control center and machine to cloud data connectivity. The framework will run in real-world power applications and interface with operational equipment. At the core of the new smart microgrid, critical infrastructure is a high-speed field data bus that connects devices and intelligent nodes. The data bus also interacts with the Central Station and the cloud taking advantage of both local and remote state to optimize operations. The data bus streamlines the delivery of real-time to analytics to any node on the network edge or cloud. It is based on the data distribution service protocol (DDS).

Things like Uber and Airbnb and things like Pandora or Spotify, which are kind of examples of Industry 4.0. So what about; does Industry 4.0 mean to sort of a power producer? It's kind of that collision between cyber and physical. Maybe a simpler way to put some of this is that smart manufacturing, IOT, Industry 4.0, is all an attempt to help take the information that you generate every day in companies — from electric energy producer processes — take that information and make some value from that information; feed that back into processes, whether it's in terms of supply chain, whether it's in terms of better-improved processes. Being able to model those processes to improve the output, the expectation of a higher-quality product. Be able to lower costs in some way, shape, or

form through lower energy, through lower material use, through reduced scrap. The idea is to take information and make value from that information. The challenge that all of these aggregator companies have is to be able to make sure that anytime hydropower or wind farms change a requirement for one of their parts that these facilities manufacture, that that is appropriately fed through the process, that there are, the plans are appropriately changed. This is a very large problem when you're talking thousands of parts for a generator, turbines, governor, controller, transformers.

Hydropower has played an important part as the critical electricity generation source of renewable energy for over a century. The digitalization of hydropower plants is transforming the way power facility will be operated and maintained in the future. It guarantees to bring substantial values to the renewable energy sector, and it is an industry-wide trend that can positively influence power networks around the world. By 2030 over half of the world's existing hydropower facilities will have undergone, upgrading and modernization, according to International Hydropower Association (IHA) [30].

Machine learning, neural network, cyber-physical systems, data mining, the Internet of Things and the Internet of Services are some of the keywords related to digitalization. It improves performance with intelligent design and common sense and reduces costs by means of save millions in hydropower operation and maintenance costs. The algorithms and models help the companies to analyze and classify the faults or, more precisely, future faults in the facility. The figure shows steps of the data collection for smart operation and maintenance of a power facility.

Figure 3. *The steps of the data collection*

As shown in Fig. 3; initially, all parts and items of the power plant, whether in the air or underwater, should be digitalized by means of a laser scan and documented regularly on a special data platform.

These stored data will later be connected to algorithms with the existing information and the multiplicity of ongoing measurement values from the facility. In order to get a precisely comprehensive picture of the whole facility, let's start by considering where and how the IoT is becoming enmeshed across the hydropower industry. Even cheap

sensors without maintenance overheads are appearing right across the hydropower operational landscape as components of the industrial IoT. Location isn't truly restricted; it can be upstream and downstream, sensors can now transmit continually, for instance, to provide water level in the reservoir, water inflow of data. When the industrial IoT begins to be shaped, the use of sensors in the hydroelectric plant also increases. The sensors can provide a continuous, high-speed data stream to inform the operation personnel of everything from stability to heat generation in turbine bearings.

Nowadays most power plant uses Supervisory Control and Data Acquisition (SCADA) which PLC boards gather data and push it to SCADA systems. However, Industry 4.0 and the growing number of internet-enabled devices in use offers facilities a fantastic opportunity to significantly increase their generation, flexibility and enhanced security with innovative solutions based on the latest technologies. The internet-of-things sensor technology and big data are advancing a new breed of power plants. A smart power plant is one which is data-rich has interconnected systems that enhanced management capabilities for property owners managers and user experience of the space customers. Smart power plants are sometimes referred to as automated plants, intelligent plants or plants that incorporate smart technology. The unit connected system found within a smart power plant work cohesively to deliver accurate and useful data that is used for enhancing operational performance personalized comfort measurable health and well-being outcomes and connected operator experiences largely mobile-phone technology. These power plants operate using integrated communication networks. It connects the systems and shares data for increased visibility and management capability enhanced operational performance and connected place experience.

There are 5 important issues in the application of Industry 4.0 in hydraulic systems. Basically:

1. Developments: The current structure of hydraulic system components is compatible with Industry 4.0,
2. Advantages: To be able to control the hydraulic structure easily in an intelligent system and to increase the system efficiency accordingly,
3. 3.Cost: Since the control from a single point is provided, the reduction in operating costs can be easily obtained,
4. Convenience: Easy monitoring of hydraulic types of equipment,
5. Alternativity: Producing alternative solutions with advanced hydraulic applications.

Major operative advantages of Artificial Intelligence with respect to hydropower facilities include limited to none a priori knowledge of involved physical experience, high level

of flexibility when managing different sets of versions and fluctuations related to discharge energy generation, and quick setup time of the forecast system. Fig. 4 illustrates a smart hydropower control system.
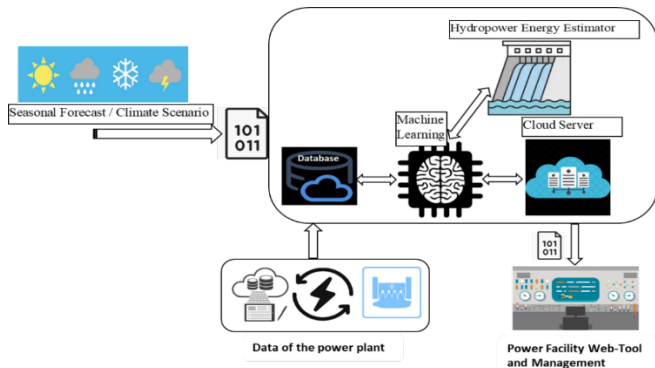
Figure 4. *Hydropower plant control system.*

The goal of this control system is to operate and manage the water reservoirs and flow rates in real-time for a continuous stable and optimal electricity production for maximizing the profit, on the global level. The dilemma here is the complex and nonlinear dynamics of hydropower plant control system.

The nonlinear dynamics of hydropower facility system can be classified as follows; firstly, on the powerhouse has its own water turbine, governor, generator, and other electromechanical equipment where any uncontrollable release of hydraulic mass by reason of water hammer can disturb the balance of the system and transfer the oscillations to the electric power grid.

Secondly the system may take time-dependent variable and random inputs such as rainfall or sudden increase or decrease of electricity market prices and water sources, in this case the system's control strategy and the operational input data have to be modified so that the variable water inflow data conditions and the electricity market prices are always utilized for optimal electricity production with negligible water losses and do not exceed the penstocks' operational capacities and reservoirs' level which means water does not run uselessly.

Thirdly it has nonlinear mathematical relationships between water inflow rates and electricity market price, in addition to the relationships between the reservoirs' levels and the consequence of generated powers are also nonlinear. Furthermore, the system has to handle uncertain requires or rejections from the grid where the input data for frequency and power adjustments may always be required.

IoT is complementary to SCADA and Distributed control systems (DCS). The data achieved from SCADA systems acts as one of the data points of supply for IoT. SCADA's target is on control and monitoring, IoT's focus is firmly on analyzing machine data to develop work rate, generation and impact top

line. The Global System for Mobile communications (GSM) module or any telemetry system to feedback the community for monitoring.

4. Conclusion

As a renewable energy source; hydropower is well-positioned to continue to supply reliable and sustainable energy. In a power facility, the noise is the voice of the machines. The voice tells us how the machines are feeling. Inspection personnel understands the voice of the machine. But who listens to the machines between the inspection rounds? Smart sensors tell us how the machine is feeling. Vibration sensors, sound recorders detect abnormalities by intelligent algorithms and machine learning. Inspectors check if something has happened in the power plant.

The digitization of hydropower plants, control systems, and power grids is an emerging industry trend that promises to optimize asset management and performance. By utilizing digitalization and the correct concepts, the hydropower industry will be able to rationalize its maintenance processes, reduction in costs and expansion of hydropower capabilities. And millions will be saved in maintenance costs! The digitization of hydropower plants, control systems, and power grids is an emerging industry trend that promises to optimize asset management and performance. Industry 4.0 can play a key role in reducing climate change.

In this study, Industry 4.0 design fundamentals, implementing and conceptual approaches as an electric energy producer in power plant analysis are given. Nowadays nations and industry companies collaborate to gain new technology with energy generation and aggregator companies. The most important reason is to use skilled sensors and to contribute actively to the power plants. Therefore, the components of power facilities should be linked to Industry 4.0 concepts is very important in terms of being able to adapt to smart, cheap operation and maintenance.

Acknowledgement

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