Key Technologies Driving Industry 4.0

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Abstract: Industry 4.0 is the ongoing industrial phase having numerous developing technologies that are coming together to offer better digital solutions in industries. Industry 4.0 has a significant role in transforming complete product life cycle form its design to supply chain into digital world. Industry 4.0 has helped industries to increased its manufacturing flexibility along with mass optimization, enhanced quality, and improved productivity. Industry 4.0 is supported by 9 important pillars. For better understanding Industry 4.0, this paper provides a brief about the associated areas such as Augmented Reality (AR), Internet of Things (IOT), Autonomous Robots, Cybersecurity, Big Data and Analytics, Cloud Computing, Additive Manufacturing (AM), Simulation, Horizontal and Vertical system integration

Keywords — Additive Manufacturing (AM), Augmented Reality (AR), Autonomous Robots, Big Data and Analytics, Cloud Computing, Cybersecurity, Horizontal and Vertical system integration, Internet of Things (IOT), Simulation

I. INTRODUCTION

Due to increase in global population the demands for the products increases over centuries. Each increasing the need of innovative and efficient ways of manufacturing of products. For Fulfilling thus need there was always a search for new ideas / technology to make it possible. Some of these new technologies generated leaps in the way of producing goods in industries. Each huge leap/jump which changed the way of working of industries is referred as industrial revolutions. Since 1800s we have experienced 4 industrial revolutions each playing a very important role which lead development of today's industries [1-6].

A. Industry 1.0

First Industrial revolution commenced during 1760s to 1840s, the emergence on Steam power machineries transformed the mode of manufacturing in the industries. Due to the transformation of hand power tools to the steam powered mechanical tools the productivity of the industry increased up to eight times of the previous. 1st Industrial revolution changed way of working in textile industry: All handlooms were replaced by the steam power machines which increased the production. The other industry which developed significantly due to steam power was transport, the bullock carts were replaced by the steam power vehicles such as trucks and trains which helped industries to reach the distinct places and increase their markets. The 1st industrial revolution played an important role in development of Iron industry, steam power, gaslighting, chemicals, cement, machine tools, glassmaking, agriculture, paper machine, mining industry [7,8].

B. Industry 2.0

The Second Revolution started between the end of 1800s and start of 1900s. The goal of this revolution was the mass production of goods by using modern technology. Industry 2.0 incorporates the new machineries which runs on electricity, the products such as internal Combustion engine, telephones, gas, rail-roads, telecommunication, water supply and sewage systems. chemical, electrification, petroleum, steel, rail, machine tools, Iron, paper making, rubber, bicycles, automobile, maritime technology, applied science, engines, turbines, fertilizer, telecommunications and business management were the most benefitted sectors [9].

C. Industry 3.0

By the introduction of computers, automation emerged in the industry. Due to the automation, there was a huge growth in production rates and efficiency of the industry,

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the industries completely automated their production lines which replaced the labor and the era of unemployment began. The robots were operated under the human supervision using electronics and software applications. The automated production line had least number of defects and the amount of wastage reduced drastically over the period of time [10,11].

D. Industry 4.0

In 21st century industry 4.0 was emerged. Industry 4.0 is the transformation of physical world with the digital world. the industries started becoming global by use of internet. It is ongoing trend of exchanging information and automation in production industries. It is the combination of cyber-physical systems, Internet of things and cloud computing. Industry 4.0 has lead development of smart factory. Industry 4.0 has helped businesses to improve its productivity, efficiency, flexibility and agility towards the upcoming opportunities, helped in developing methods of collaborate working and knowledge sharing, it made compliance easier and makes better customer experience with the company [5,7,8,11].

II. TECHNOLOGIES DRIVING INDUSTRY 4.0

Industry 4.0 is supported by 9 technologies which bridges the digital and physical world together and develops the autonomous and smart industries. Modern industries, businesses and supply chains are already using some of these technologies but when all these 9 are used togethers enables industry 4.0 to work at its max potential as shown in Fig. 1.

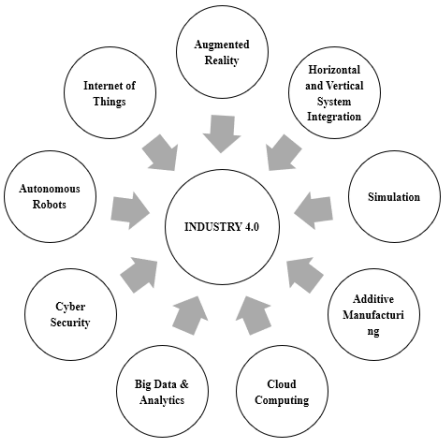

Figure 1. Key Technologies of Industry 4.0

A. Augmented Reality (AR)

AR denotes to the incorporation of extra information produced by computer into a real-life ecosystem. AR enhances the user's experience by providing the interactive interface in real time. It helps user to work and access the application together. By the introduction of mobiles, have eliminated many restrictions of AR developments, by use of mobiles there are several apps available which gives AR experience to users [12]. AR permits users to connect the gap among the physical world and digital environment. During year 2018 – 2025 the Industrial AR's growth rate is expected around 73 % to 74 %. The combined share of industrial AR in market is expected to grow up to $75 billion in 2025 [13].

AR comprises a number of technologies that makes usage of electronic devices to indirectly / directly view a real-life ecosystem that is linked with virtual components. The elements which are responsible to make AR system includes: a component to capture pictures, A display showing virtual information, A processer for processing virtual data, an element to trigger the display showing virtual data [14]. AR benefits the utilization of visual elements rather than text, and deliver necessary information to users [15]. Applications of AR can be found in domains like products inspection, maintenance assembly-repair, Human-Robot Collaboration, training and building monitoring [16].

B. Internet of Things

Internet of Things (IoT) is described as "Complex system of physical and software which are applied within smartphones, desktops, electronic devices, sensors along with other devices having software to execute computing / non-computing events" (see Fig. 2) [17]. IoT is new example which is quickly increasing its importance in the current wireless communications environment, concept is the widespread existence around us of a range of things like sensors, cell-phones, actuators, radio frequency identification tags, etc. that through particular addressing schemes that can work together with each other and collaborate with their neighbors to accomplish shared goals. High effect on different parts of normal life and the behavior of potential users is major strength of IoT idea [18]. In Industry 4.0, It is probable that IoT can provide encouraging innovative methods for operating many current engineering organizations in the digital initiatives of tomorrow's complicated engineering ecosystems. As per GTAI (2014), IoT is discovering its path into manufacturing all while revolutionizing the current production methods; therefore, it is believed as a major supporter generating advanced manufacturing, Industry 4.0 [19]. Due to impact of IoT many business models are developing where IoT work as a stage which links user digitally through internet [20]. IoT enables actuators, sensors, and other devices to communicate effortlessly in a smart environment. It has been broadly used in mining, healthcare, supply chain, firefighting, logistics, transportation, building automation, asset tracking, smart grids, intelligent home, energy management and smart city [21].

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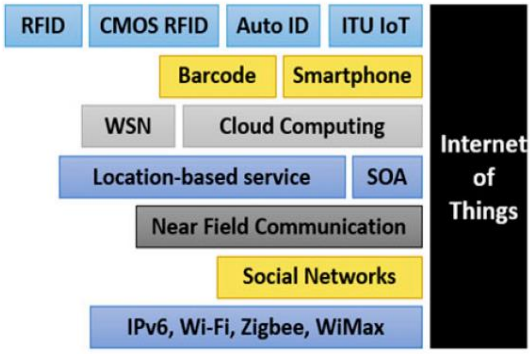

Figure 2. Components supporting IoT [19]

C. *Autonomous Robots*

In latest years, upcoming challenges to make manufacturing processes autonomous, customizable and more efficient have resulted industrial revolution. Industry 4.0, a innovative idea of industry has developed and is presently implemented to designate the present trend of robotics and data transfer in production technologies by forming a "smart factory" [22]. In modern manufacturing industry robots are playing a vital role. In Europe since 2004 use of industrial robots have been doubled. Autonomous manufacturing methods which are driven by robots which can carry out tasks safely with efficiency, versatility, cooperation and flexibility in Industry 4.0 [23].

AI workers or software robots that can execute accurately, repetitive tasks are used for automation. Developer sets the task instructions with the help of defining variables and screen recording [24]. Increased attention has been given to intelligent robots, as well as robots connected to the cloud [25]. Robotics will be having a vital part in this development since advanced solutions and technologies, conventionally linked with the service robotics area, is shifting to smarter industrial robots, taking advantage of the growing localization, navigation, motion control technologies and sensing. Development in Machine learning helped in manufacturing smarter robots which reached industries in reaching desired goals [26].

D. *Cybersecurity*

Before the development of Industry 4.0, the aim of cybersecurity was to protect data at organization level. As Industry 4.0 is based on IOT, all data is connected with internet which becomes an easy target of hackers and increases the chances of leak. Due to this reason cybersecurity has become an important part of the company/organization. In the era of Industry 4.0, there are many reasons which makes very difficult to protect the company & its data from various cyber-attacks such as [27].

Due to the emergency and connected nature of Industry 4.0, The flow of data and intellectual property across all the sub-facility of the industry is shared mostly by cloud. All system across supply-chains is being connected to internet (cloud-based software) which makes it easy for any cyber leak [28]. Due to Industry 4.0 the complete network of data/cloud has many stakeholders, company users, consumers accessing it from various systems. Due to this the number of access point to the network drastically increases and can serve as one of the points of attack. This makes role of cybersecurity more critical [29,30]. Fig. 3 shows the flow of data in an enterprise during complete product life cycle.

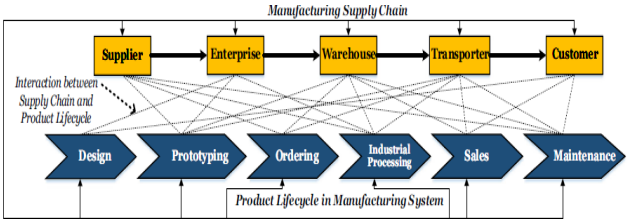

Figure 3. Network showing the flow of Data and Multiple Access Points throughout the Product Lifecycle [30]

E. *Big Data and Analytics*

Industry 4.0 is a combination of various revolutionary statistics and communication technologies which leads in early fault recognition and stoppage which increases excellence, agility and efficiency. Big data and analytics is an important part driving industry 4.0. Big data comprises of large size, high authenticity, and large diversity of information. In production organizations, there are huge, varied, organized / unorganized information which is obtained by sensing instruments, various electronics, log files, mics and cameras in real time. Obtained from several automation stages, industries, operation work, etc. [31]. Through the combination of IOT and CPS, the volume and diversity of information generated will be massive. It delivers valued understandings helping the working of smart factory management. This situation creates large amount of data which is needed to process with unconventional methods and technologies to provide appropriate information [32,33]. This data which is obtained from industries is called as industrial big data. Big Data has many applications in modern industries.

In manufacturing industries, large number of mechanical parts are produced every day. It is very difficult to maintain the quality of parts and detect the amount of wastage, while manufacturing there are risks of production of poisonous gases which can cause disasters, also maintenance of the machinery is important. Advance IOT Monitoring such as cameras, Gas sensors have helped manufacturing industries to monitor the above problems and solve it beforehand. It has helped industry to keep its quality maintained [34,35].

In Medical Industry, Big Data is an important part of future generation in the medical field. to discover the periodic forms which might turn out to be virus, mock-ups can be trained to monitor its actions on human. This helps the medical industry to find or warn the system about any

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outbreaks of virus in early stages and prevent deaths or illness. It also helps to develop vaccines, medicines etc. easily [36]. Big Data Analytics have also helped to improve other industries such as agriculture and sports (see Fig. 4).

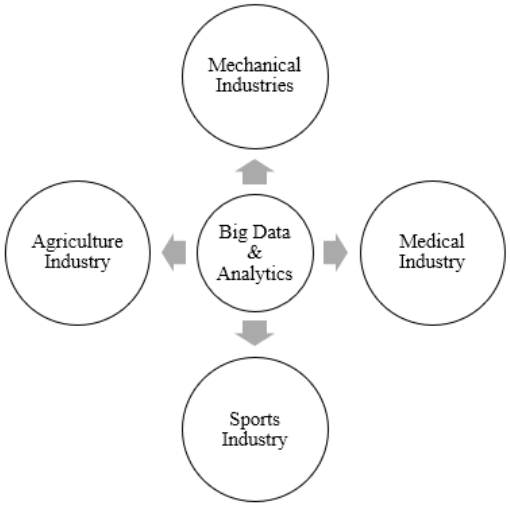

Figure 4. Industries which are benefited by Big Data & Analytics

F. Cloud Computing

Cloud computing is transfer of variety of services via Internet. These comprise tools and applications like, servers, software, databases, data storage and networking. In Cloud computing data is retrieved and created remotely in cloud / virtual space. Users can upload and save their files and other applications on cloud platforms which can be accessed from anywhere, anytime easily by using internet. This gives user flexibility to access data at any location on earth without bothering where it is stored or without being present at the server rooms [37,38]. There are 3 types of cloud computing services (see Fig. 5):

1) Software-as-a-service (SaaS):

In this type an application is provided as a service to customer across internet. It is a business software. SaaS software does not need to be installed on the consumer's desktop/laptop; it can be accessed using internet browser [39]. Some of the examples of SaaS are; Google Maps, Dropbox, WebEx, etc.

2) Infrastructure-as-a-service (IaaS):

IaaS is an online cloud service that provides Infrastructure (hardware) as a service. User can use variety of virtual computer services such as CPU, network and storage components. Cloud users can use these infrastructures to run their various software which they are unable to use on their own hardware. This helps them to solve or run applications which require heavy hardware easily [40]. IaaS Examples are; Amazon Web Services, Cisco Metacloud, Microsoft Azure, Google Compute Engine.

3) Platform-as-a-service (PaaS):

It is a set of all kinds of development tools and resources which provides users a complete package which includes IaaS and all kind of supporting software for developing small applications to enterprise level application. PaaS helps users to avoid buying licenses of different software and expensive hardware to support it. Examples of PaaS are; Heroku, Azure, Force.com, OpenShift, Google App Engine [41,42].

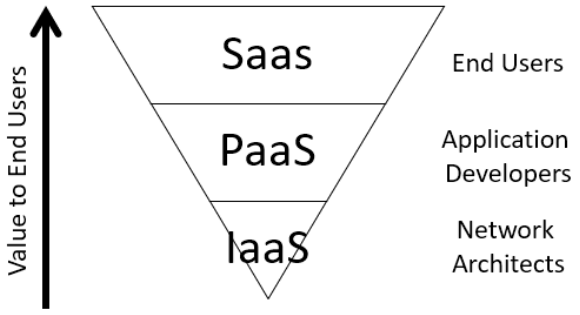

Figure 5. Stages of Cloud Computing

G. Additive Manufacturing

Additive Manufacturing (AM) / Rapid Prototyping / 3D Printing is an emerging field in manufacturing which can create/print 3-Dimensional Parts [43-45]. In 4th Generation of Industrial Revolution AM has played a significant role as the important factor of success in manufacturing world [46]. AM uses Layer-By-Layer manufacturing technique gives advantages to current designers to design most optimized parts with much higher complexity, which were impossible to manufacture with current conventional techniques. AM has its wide applications in Medical, Automobile, Aerospace and Consumer Product industries [43].

In recent time there is noteworthy development in AM and many technologies such as Selective Laser Sintering, Stereolithography, Fused Deposition Modelling [47], Selective laser Melting, Electron Beam Melting [48], etc. has been developed each having its advantages in their respective industrial applications. AM technology offers wide range of materials for printing which are mainly classified into following groups: composites, ceramics, metals and plastics which are available in liquid, solid sheets, filament or paste and powder states [46].

In industry 4.0 AM shares its applications in medical fields for manufacturing custom light weight prosthetics for the users, also for manufacturing artificial ligaments, tissues etc. It helps to manufacture custom made tools which are used in surgeries etc. In manufacturing, Automobile and Aerospace Industries AM is used to manufacture light weight and performance optimized components to increase the overall efficiency of the machine/vehicle/aircraft by making it lighter [49]. AM helps the industry to work at its optimum levels by helping them by saving its cost of manufacturing and by avoiding the wastage of raw materials [50].

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H. Simulation

Simulation also referred as a virtual twin/digital twin of the real-world machine/system/process based on the results of IOT database. These virtual models are connected with IOT and are experimental which makes user to conduct all kinds of tests on it in virtual world. This virtual model of the real-world system helps the business/industry to get the results of various tests virtually and helps them to understand, analyze and improve the product before manufacturing it and testing it. This provides new foundations for simulation-based engineering [51,52].

These simulations are around 90% accurate and can be used by using factor of safety. These simulations help to save huge cost of testing and prototyping the process at the initial stages of development and helps to improve digitally at early stages. This helps to recognize the failures in the system and helps to find solution. This helps to create complex models, smart applications and systems, difficult algorithms and get their results on one click [53]. Examples of simulations in industry 4.0 are as shown in Figure 6

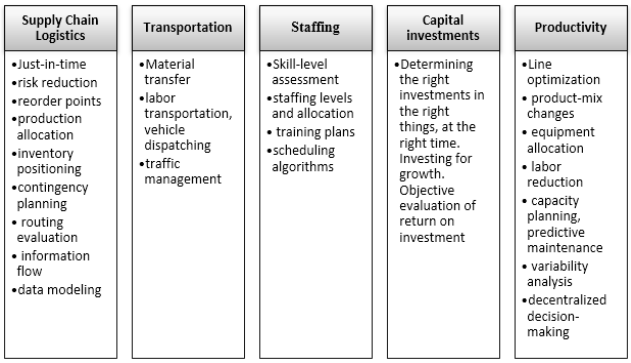

Figure 6. Use of Simulation in Current World

I. Horizontal and Vertical System Integration

Vertical and Horizontal integration are strategies that businesses use to maintain their place between their competitors.

The aim of Vertical System Integration is to bridge all levels in the organization from the production stage up to Research and Development, quality, IT, product management, sales and marketing, etc. In this Integration to get data-driven tactical and strategic results the data flows transparently without any restrictions within these sages. The vertically integrated enterprise increases a competitive gain by obtaining new opportunities from varying marketplace [54].

The aim of Horizontal System Integration is to focuses pm acquiring or establishing partnerships with other similar companies in the market to improve its value chain. It also focuses on increasing the size of the company, improving scale of company's economy, increasing its power in market by acquiring its network of distributors and suppliers, improving its product range and services, also increasing its market by entering in new markets or by reducing its competition [55].well they fit a coherent and balanced technical program.

III. SUMMARY AND LITERATURE GAP

Table 1 gives the characteristics and advantages of each key element in Industry 4.0.

Table 1. Summary of all key elements in Industry 4.0

Technology	Characteristics	Advantages in Industry 4.0
Augmented Reality	Overlay of Real and Digital world Real-time interaction Registration and Alignment in 3D	Improves Customer Engagement Provide a Personalized Experience Increase Customer Satisfaction New and Efficient Marketing Methods Facilitate Employee Training
Internet of Things	Connectivity Intelligence Energy Safety Sensing Communication	Helps to Reduce Cost Improve Operational Equipment uptime and availability Increases Speed Improves Product Quality Improves Safety Standards
Autonomous Robots	Perception Decision Actuation Humanoid / Non-Humanoid	Increase's Production Rates Reduces Defects and Wastage Ensure Tighter Quality Control Better Flow and Control of Information across Supply Chain Reduce costs across various parts of Production Helps to Increase Sales
Cybersecurity	Threat Detection & Forensics Privacy Cyber Assessment	Protects System against Viruses, Worms, Spywares and other unwanted software Protection against data leak Protects against hackers Minimizes Computer freezing and crashes Gives Privacy to users
Big Data & Analytics	Variety Veracity Value Volume Velocity	Cuts costs. Increases efficiency. Improves pricing. Helps to compete with big businesses. Allows you to focus on local preferences. Helps you increase sales and loyalty.
Cloud Computing	On Demand Self-Service Broad Network Access Resource Pooling Rapid Elasticity Measured Service	Cost Savings Easy and Fast data sharing Centralized Storage of Data Can be accessed from anywhere Fast and Reliable Elimination of expensive hardware
Additive Manufacturing	Accuracy Precision Complexity Material Variety Cost time	Higher Complex Structures can be manufactured Lower Cost for Prototyping Good Accuracy and Precision Wide Material Availability Saves Time

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Simulation	Virtual ValidationFast & ReliableAccurate	Gives Fast and Accurate resultsSaves time of prototyping and Testing at Initial stagesHelps to determine critical problems at very start of the project.Saves Money and TimeReduces time for Product Development
Horizontal & Vertical System Integration	Customer Analysis Purchase / Supplier Partnering Demand and Lead Time Management Storage and Transportation	Increased market shares Larger consumer base Increased revenue Reduced competition Synergistic efforts Create economies of scales and economies of scope Reduce production costs

The emergence of Industry 4.0 brought significant changes with its innovative and efficient technologies which also opened ways for the researchers to study different aspects of all the key elements in various fields and bring innovations into the same improving the industry. Research can help to develop improved system integrations and system architectures. This must be done by taking account of increasing of the cyber-attacks and cybersecurity must be improved.

IoT (Internet of Things) is a revolutionary technological revolution which is completely dynamic in nature. It is a combination of various revolutionary technologies which is evolving continuously. In the industrial view, IoT is a solution for improving efficiency, supply chains, development of smart robots, etc. This opens many research areas such as IoT Network Design and Architecture, IoT enabled Software Architectures and Middleware, Mobile Cloud Services, Data and Knowledge Management, Context-awareness and Location-awareness, Software-defined Networking, IoT Services and Applications, etc. Cybersecurity plays an important role in protecting vulnerable resources from various cyberattacks. In the industry 4.0 the system is shifting towards cloud-based solutions which makes cyber-security to improve itself in various aspects. There are wide range of research topics which needs to be studied such as: 1. Information security (Computer Network Security, Application Security, Web Services Security, Mobile Security, Protective Security, Software Security, Wireless & Sensor Network Security, etc.); 2. Digital Services (Web Services, Internet Banking, E-Booking, E-Government, Electronic Commerce, Citizens Public Online Services, Mobile Commerce, E-Postal Services, E-Health, E-Learning and Online & Virtual Education, Secure Protocols, Coding and Development, etc.); 3. Protection of Digital Services (Protection of Business Information Systems, Protection of Online Services, Public Online Services, Internet Banking, Security, Trust, Privacy, etc.).

IV. CONCLUSION

Brief idea on Industry 4.0, that brings efficient, clever, personalized, effective and customized manufacturing with optimum price has been discussed.

Industrial revolution is the crucial reason of Industrial development. In each revolution innovative and new technologies are used to fulfil customer's demand by gaining profits in industry.

Industry 4.0 played a vital role in developing smart industries by bridging physical world to the digital world.

The 9 key technologies which are driving the Industry 4.0 are discussed in details.

It is observed that the advantages of stepping into Industry 4.0 could overcome the related prices, predominantly for first-in-class manufactures possessing essential knowledge and workforce for creating and implementing fundamental technological trends, and have enough backing from investors for investing in innovative technologies.

Industry 4.0 promises increase in flexibility, speed, mass customization, improved quality and increase the productivity in manufacturing industry.

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