CHAPTER SIX

Renewable energy system for industrial internet of things model using fusion-AI

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6.1 Introduction

Energy plays a crucial role in the global economic environment. The vital infrastructure includes electricity systems, which play an essential role in human life by supplying energy to meet home and industrial needs. Because power systems have human lives and expensive infrastructures such as turbines and generators, their automation mission becomes vital. According to the global energy perspective, roughly one-eighth of the world's population does not have access to electricity [1]. The major drivers of change include decarbonization, reliability with increased demand and transport electrification, customers with empowerment, market designs, and regulatory paradigms. The variables that make it feasible are advanced technology, policies, and standards [2]. Generation, transmission, distribution, and consumption are all factors in the supply chain. The transition from a centralized to a more distributed architecture is readily apparent. Turbines, generators, circuit breakers, switches, transformers, and other essential equipment are part of the industrial internet of things (IIoT) supply chain. Power system control, sensors [3], communication switches, monitoring and data acquisition, and distributed control systems are examples of secondary equipment used in automation. These measures are based on the voltage and current measurements' protection functionalities. Microsecond reaction times are required in power systems to isolate the defective portion using open-loop control.

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Closed-loop control with feedback is included in the controls. This only takes a few milliseconds. In the Industrial Age, energy efficiency [4], power generation, and sustainability are critical 4.0 [5]. Energy suppliers that are sensitive to rising usage of resources and scarcity and the environment are focusing on sustainability. Developed countries such as India and China have growth rates of up to 25%. Electrifying energy distribution, growing energy consumption, increasing dynamic electrical charges, Renewable Energy, and increasing dispersed power are the four essential themes. This research work examines the first landscape of Renewable energy systems (RESs) and their future evolution and future developments. The IoT is a critical component in the Industry 4.0 [6] shift. Intelligent factories can leverage IIoT technology to improve worker efficiency, safety, and output by integrating it into a wide range of machinery.

6.1.1 Renewable energy system for smart production

It is feasible to communicate and construct a linked plant by integrating intelligent technologies into production machines and processes [7]. Employees can access all data collected from this connected gadget in a central database. Managers can get a complete picture of the facility by storing data in one place. They can observe when specific machinery parts were in use, as well as details regarding their performance. They can also learn how many resources areconsumed, Energy consumed, how many units are created, and other information.

6.1.2 Energy management for renewable energy system

Because industrial operations are frequently energy-intensive [8], even little improvements in energy management can help industrial enterprises save considerable money while also improving their environmental performance. With IIoT, managers can better understand a company and facility's energy usage for RESs. Each machine's energy use can also be seen in detail. Companies can use data from intelligent sensors to optimize their energy use. It is possible to discover which machines consume the most energy and which machines are inefficient. It can even assist in the addition of renewables to a system.

6.1.3 Predictive maintenance

Industrial organizations can benefit from IIoT by improving their predictive maintenance programs and increasing their efficiency. The monitoring of equipment condition and performance to predict failure is known as predictive maintenance. The worker can avoid these failures by performing routine maintenance. Reactive maintenance, on the other hand, is when personnel fixes a machine after it breaks down. Intelligent sensors can provide specific information on how a machine component operates, allowing users to detect faults sooner and more precisely. Workers may be alerted to odd operations or potential issues. IoT-enabled predictive maintenance [9] helps businesses decrease downtime and increase productivity save the energy for RESs.

6.2 Related work

Puri et al. [10] this research work uses several sensors to construct a system that uses residential appliances and industrial places. The power generating circuit connects a variety of sensors, including a piezoelectric sensor, heat from the body, and a solar panel. Two artificial intelligence (AI) models, the artificial neural network (ANN) and the adaptive fuzzy inference system, are used to calculate the total energy generated from renewable energy resources (RERs).

Bedi et al. [11] by replicating biological nerve systems, both on the fringe and on the device, with cognitive calculation, streaming, and distributed analytics, the development of computer intelligence skills can produce an intelligent IoT system. The electrical and energy transformation systems are examined in this review study.

Sherazi et al. [12] across various sensor intervals is the main result of these surveys. This shows a linear increase in the total cost of £1500 in the industrial environment (nonenergy harvesting) over 5 minutes. The EH scenario tends to reduce up to 5 times after a given interval. Furthermore, carbon emissions from LoRa motes were measured at up to 3 kg/kWh in renewable sources, with yearly CO_2 emissions savings of up to 3 kg/kWh. The findings of this study could be crucial for a green business that strives for cost and energy efficiency.

Islam et al. [8] the electrical supply to specific residential loads was revealed in this study, to lower energy expenditures owing to environmental consequences.

Clairand et al. [13] energy efficiency methods are critical for this particular industrial sector. The different energy efficiency potentials in the food business are explored in this article—first, a quick rundown of the primary food industry and their respective energy use. The various energy efficiency options for thermal and electrical energy are then discussed. Industry 4.0 and demand response have also spawned new trends and opportunities.

Tuttokmaği et al. [14] fourth Industrial Revolution. Optimization, automation, energy efficiency, smart production, and the internet are all prevalent themes in the Industrial Revolution and Smart Grids. This research looks at how these process smart grids interact with one other and the process of building the Industrial 4.0 revolution globally and in our own country.

Ke et al. [15] optimize data transfer delays, energy consumption, and bandwidth allocation simultaneously while avoiding the dimensionality curse caused by a complex action space. By learning from the dynamic IoT environment, JODRBRL can reduce the entire cost of the system, including the cost of data buffer delays, energy usage, and bandwidth.

Hossain et al. [16] long speed long short-term memory (LSTM) and a fully connected neural grid are all part of the hybrid algorithm. Sophisticated models such as the multilayer neural network (NN).

6.3 Internet of things in renewable energy sector

Renewable energy sources will, without a doubt, be the dominant sources of energy in our future. Their adoption has been continuously expanding, allowing for the development of intelligent energy solutions. These resources are unquestionably preferable to those that release hazardous gases, which are already scarce. Renewable energy [17] is being deployed at a breakneck pace that is also cost-effective. Modern disruptive technologies [18] can help to improve the use of RERs. The use of IoT in the renewable energy sector has significantly increased. IoT applications helps to overcome several barriers to renewable energy adoption. Here are a few examples of renewable energy IoT applications that contribute to a more sustainable future:

6.3.1 Automation to advance complete production

Solar and wind energy are the most widely used renewable energy sources [19]. They have contributed to their quantity and dependability more than any other renewable energy source. In 2019 windmill farms provided enough energy to meet a fifth of Germany's energy consumption. Energy costs related to the creation of these resources [19] have decreased significantly. Solar panel prices have dropped by 99% since 1977. Germany, China, and Japan are the world's top solar energy producers. The integration of IoT with sensors in solar and wind systems can improve their dependability even more. To ensure optimal energy production efficiency. Analytical solutions [20] can be used to track the sun's movement, and the angle of the solar panels can be altered automatically. In the realm of wind energy, IoT [21] may be used to track various metrics related to electricity generation.

6.3.2 Smart grids for elevated renewable implementation

Traditional power grids cannot encourage this reliance on renewables based on weather conditions. Smart grids have been built due to the IoT [22], allowing for manual power disruptions between renewables and established power plants. Smart grids have aided in supporting the various characteristics of renewable energy and ensuring a continuous supply of energy to users.

6.3.3 The internet of things is increasing renewable energy adoption

The IIoT-enabled [23] development of intelligent grids has boosted the rise of renewable energy sources. They provide tremendous advantages in energy consumption monitoring and real-time notifications, allowing energy utilities to integrate renewable energy sources. The following are a few of these advantages:

6.3.3.1 Energy expenditures

End-users are now using renewable energy to lower their energy expenditures [24] and become self-sufficient. Many countries, such as India, provide solar subsidies to their residents to boost the usage of renewable energy. Countries assist residents in constructing solar plants on their rooftops for personal energy requirements.

6.3.3.2 Balancing supply and demand

Energy utilities use IIoT smart grids to ensure that consumers have a consistent supply of power. Integrating IoT [25] with renewable energy allows suppliers to accept renewable energy while also meeting the needs of end customers. Intelligent energy meters are being used commercially to supply electricity suppliers with real-time consumption statistics. They can also use analytics and data processing tools to establish trends and patterns related to high-load scenarios. As a result, utilities can utilize the manual switching technique to limit the utilization of power plants during regular off-peak times and then run them during times of excessive electricity demand. Utilities can thus manage supply and demand while also limiting dangerous material emissions into the environment.

6.3.3.3 Cost-effectiveness

According to studies, if only 12% of Saharan solar energy can be used, the world's energy needs can be supplied (around 110,400 km^2). However, there are still a few drawbacks to this strategy. It is challenging to create and operate a large solar farm [26], for example. Furthermore, electricity from this remote area will be subject to transmission and distribution losses. Power losses in transmission lines, for example, can approach 10% over long distances. These obstacles and stumbling blocks are impeding the expansion of solar power and renewable energy in general. The usage of IoTs in solar energy could help to minimize construction costs and solar station management. The real-time monitoring and forecasting analytics capabilities of the IIoT can be utilized to keep track on characteristics that can reduce power plant efficiency or result in unforeseen failures. As a result, businesses can save money on inspections and repairs while increasing efficiency.

6.4 Proposed methodology

IIoT can establish a comfortable working atmosphere within the building using IoT smart industrial environment sensors. Temperature and moisture sensors, leak and water sensors, air and air smoke sensors, and light sensors are among the IoT's [27] intelligent environment sensors. Humidity and temperature sensors: these sensors keep track of unanticipated variations in the temperature. Temperature and moisture sensors are also used to save energy by turning off refrigeration and heating while no one is present. Heating sensors, thermometers, thermocouples, infrared sensors, bimetallic devices, silicon diodes, and state change sensors are only a few examples. The following are some examples of temperature sensors: Humidity sensors can include resistive sensors and capacitive sensors. Leak and water sensors: Sensors warn homeowners to a leak, preventing costly floods. Water and leak sensors under carpet leak sensors, rope-like sensors, and hydroscopic tape-based sensors are examples of leakage sensors and water sensors. Leak and water sensors are two examples. Smoke and air sensors: these sensors keep track of indoor air quality. Smoke and air sensors allow IIoT workers to detect smoke, carbon monoxide, and any other harmful gas in their industry. As a result, industrial employees will take corrective action [28] before anyone in the industry suffers major harm. Smoke and air sensors include photoelectrical, sensor ionization, dual, inhalation and vapor sensors, projected beam sensors, video sensors, and heat sensors, to name a few.

6.4.1 Interruption attacks

A hardware or sabotage DoS attack and a software-based DoS attack are examples of interruption attacks. denial of service attack (1) counter-sabotage and sabotage (2) network device disconnection by methods of IoT [29] device hardware or infrastructure sabotage (e.g., cable cutting or damage caused to the physical IoT device). Cutting the link between PMU and PDCs and Super PDCs, or causing a physically damaged connection to PMUs and intelligent meters, are examples of EPES sabotage. Sabotage of the RES is another example of sabotage. Electric power plants are equally susceptible to sabotage. Attacks on vital IoT infrastructure can be reduced if access to it is restricted. Execute attacks and counter-attacks During a DoS attack, the attacker hacks several workstations (or zombies) and consumes network resources, overloading the target bandwidth and slowing or stopping legitimate traffic (also known as DDoS).

DoS attacks, for example, are causing delayed and lost measurements from devices that rely on real-time measurement data on RERs (e.g., PMUs and smart meters). As a result, the transmission system [30] condition, the delayed resolution of power system problems, or the complete failure of network measurement equipment cannot be reliably forecasted. Network layer assaults, transportation layer attacks, denial of service attacks on the Local Area Network, and teardrop attacks are all examples of DoS attacks. During teardrop attacks, attackers send fragmented packets to a target. Due to a flaw in reassembling the TCP/IP fragmentation, the target cannot reassemble the received packets, resulting in overlapping packets that crash the target network device. DoS attacks can severely harm the IIoT. As a result, network security mechanisms like air gaps, anomaly detection, huge pipes, and traffic filtering must be used less frequently. An airtight network is a network security solution that physically isolates a secure computer network from other dangerous networks public Internet or an insecure local area network. It disables nonlocal segment machine connectivity. The expensive expense of constructing separate network infrastructures, for the other hand, is a drawback to this method. Network DoS attacks are detected using anomaly detection techniques. Experiments revealed [31] that detection performance is inverted concerning network usage. The utilization of the network is also essential in determining the best detection parameters. Significant bandwidth connections are networks capable of absorbing attacks to mitigate DoS attacks. The high expenditures connected with this approach, on the other hand, constitute a disadvantage. Filtering traffic is a less expensive technique to protect networks against DoS assaults [32]. This approach employs a distributed or redundant infrastructure to reroute attack flow. This technique, however, has significant flaws, including a lack of documentation to back up the assertion that DoS traffic is filtered from ordinary traffic and the difficulties in implementing it.

The economic impact of the IoT on energy and electrical systems McKinsey For energy and power systems, While proposed approach offer huge revenue prospects, these outstanding numbers must be evaluated against the high costs associated with implementing new IoT devices [33] and technology. The surplus generated, on the other hand, exceeds the starting costs. In addition, IoT technologies can be used to save money on current devices and IIoT infrastructure. Connectivity, cyber security [34], massive data management, personal privacy, low-cost, sustainable power resources, or dependable sensors are now preventing IoT devices and technology from entering the market. To overcome these obstacles and ensure that the IoT for IIoT continues to grow, viable solutions are required. Energy and electrical power systems the IoT has an impact on the environment. In IIoT, power is used more efficiently with IoT. Control systems [35] have also been tweaked to maximize the use of renewable energy sources (solar and wind). This has a favorable influence on the environment by reducing energy waste and carbon dioxide (CO_2) emissions. Annual CO_2 emissions are predicted to drop by 2 gigatons by 2020. The social influence of the IoT on energy systems and electricity As the world's population grows, it becomes increasingly important for individuals to look after the planet's resources. Health, comfort, and convenience are increasingly personal priorities around the world as living standards rise. IoT can meet all of these demands and wants by sensing, gathering, transmitting, analyzing, and sharing large data. Organizations and institutions will use the IIoT to boost energy efficiency, control, and audit skills to achieve these standards. When hacking the smart meter, more personally identifiable data gathered from the meter could jeopardize personal security (e.g., data on energy use and user movements and activities to track data). A hacker, for example, could be able to tell whether or not a user is at home or whether or not a child is there. While IoT deployment in RES [36] for IIoT Model Using Fusion-AI poses a cyber and privacy risk, numerous social benefits include improved lifestyles, public safety, energy conservation, cost savings, and a healthier environment. Our proposed system also hasmany advantages. Individuals and businesses must decide on the best use of technology for their requirements based on these negotiating agreements—inability to push IoT adoption into society and gain widespread acceptance. People enjoy being in charge of their own well-being. Given the numerous benefits of deploying IoT technology, many people may be eager to give it a shot. Even if we are aware of the benefits, some people will be resistant to this technology. Furthermore, international rivalry for excellence in the manufacturing and development of IoT devices [37] makes it difficult for a company to establish a foreign base and deploy its resources. People's choices should be respected in all instances, and they should not be coerced onto a road that makes them uncomfortable.

There are several benefits to integrating IoT with RESs but there are also several obstacles. These problems include sensing, networking, power management, massive data, computers, complications, and safety [38]. Technical advances are required to meet these problems and produce an intelligent cyber-secured electric power network for RESs.

Renewable Energy Sources Integration: All through the last decades, the incorporation of renewable sources, mainly photovoltaic (PV) (solar PV system) are setting up and wind energy plants have led to a considerable dynamic characteristic changer in power systems. This alteration is mainly because the majority of renewable have different characteristics, availability/ certainty on energy. To integrate a huge sum of renewable energies into the open power system network, reconfigure the existing energy systems dynamics. The distributed nature of renewable sources

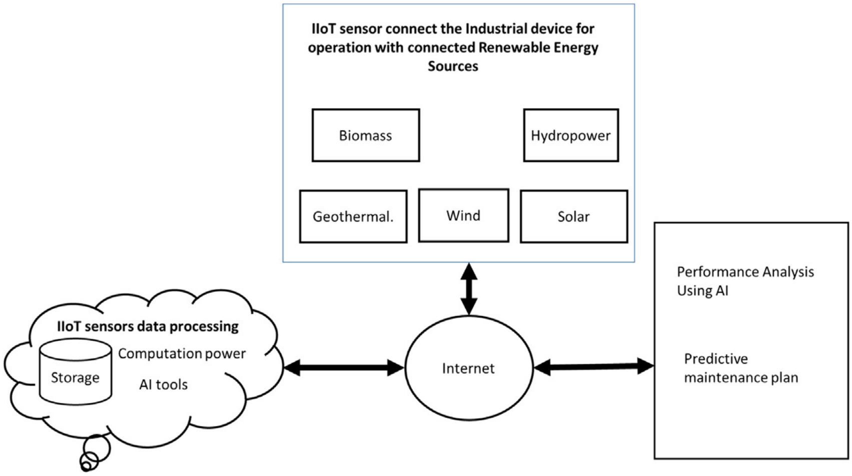

Figure 6.1 Renewable energy system for industrial internet of things model using fusion-AI.

(i.e., wind power, PV, biomass, fuel cell, etc.) is the future of reasonably priced power systems (Fig. 6.1).

6.5 Renewable energy system for industrial internet of things model

The difficulties are especially apparent in distribution networks when planning, operation, and maintenance are challenging. Integration of renewable energy sources and electric vehicles, energy storage, demand-side management, lighting and propulsion equipment, and response to recent extreme weather occurrences are examples of this. The services emphasize customer service, system dependability, and operational resiliency. Energy storage could provide some load support. This necessitates metering equipment, system monitoring, and control that is more modern and IIoT [39] protection systems. These are the difficulties:

1. Solar PV Rooftop with Distributed Resources Integration (DRI) is becoming increasingly popular. Wind turbines and fuel cells are two more prominent choices. It has the option of being connected to the grid or not. Utility-owned DRIs can be set to have the least amount of effect. DRIs are largely unpatched and has no impact on system

capability. These are not restricted in terms of frequency [40], but they continue to contribute to capacity deferment.

2. Energy storage planning and implementation There are chemical, thermal, and mechanical techniques. Energy storage separates energy production and delivery in minutes, hours, and days. Load shaping, maximum load delay, addition/backup power, power arbitration, power control, and frequency control are some benefits.
3. Transmission Systems Interfacing historically, two separate systems have been conveyed and distributed. With the bidirectional power flow, the lines are blurring. Between medium voltage and low voltage (LV), converging lines form (LV).
4. Natural factors and their effects on Tsunamis, monkey devices, and blackouts are examples of extreme weather disasters that destroy equipment. Modern weather forecasting allows operators and planners to plan for and rebuild damage avoidance infrastructure. By building redundant/direct communication paths beneath the feed system, circuits beneath the feed system help to improve system dependability and minimize service interruptions.

Microgrids [41] are one method of implementing distributed control, and autonomy is also discussed. Controlled and coordinated electricity distribution systems incorporate loads and dispersed energies that can be operated on an electricity grid or isolated. Microgrids [42] are similar to hybrid cars in that they are partially powered by electricity and have battery-shaped storage to ensure a constant supply. Because renewable sources, such as the sun, are intermittent, a reliable, nonenvironmentally friendly source must be included. The necessity for massive sensing capabilities, a safe and reliable communication system, Standard Interoperability, data management, viewing, archiving, data detection unsuitable, time synchronization, and data security and sharing are among the lessons learned from deployments around the world [43]. Only 20% of respondents say data might be used in industrial processes. According to McKinsey, It's also vital to have distributed intelligence. For distribution and privacy, emerging technologies necessitate cybersecurity.

In this work, we used a four-step methodology: (1) gather and process data, (2) send data to the cloud server, (3) develop the model, and (4) validate the model using the Fusion AI ANN. Fig. 6.2 depicts the proposed IoT model.

A piezoelectric module, electric body heating, and solar panels for sustainable energy are among the three modules. For the first component,

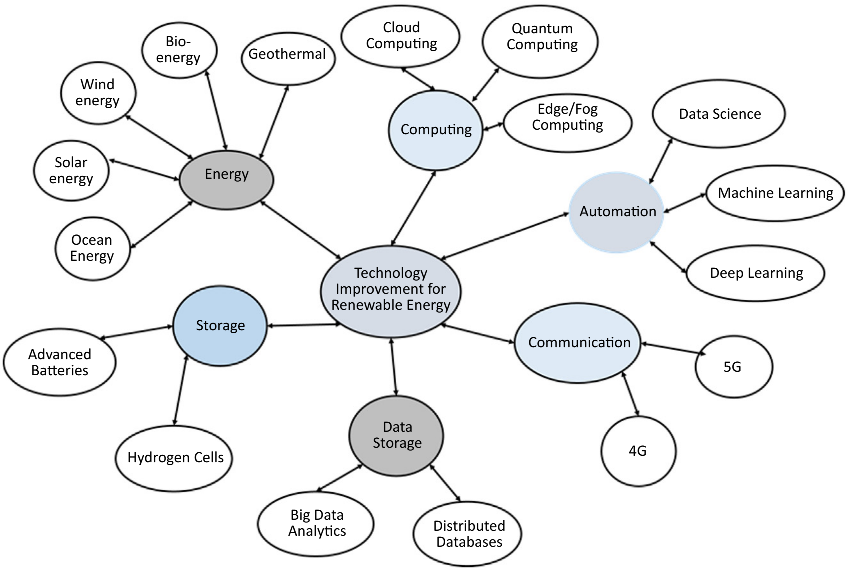

Figure 6.2 Technology improvement for renewable energy.

sensors can be deployed anywhere in the world (Fig. 6.2). Working of some IIoT device work for Mechanical tension is turned into the Working of some IIoT device electrical energy and output are pressure and pressure in the sensor.

The second component uses the heat produced by the Working of some IIoT device. This is monitored by the sensors, which send heat to the converter and the electrical producers. The sensor is coupled to a power storage device, which stores the electrical energy produced by the sensor. The energy is stored in the store and used for various things, including mobile charging and headlamps. The equation for this component is as follows: where is the Stefan-Boltzman constant (0174 Btu/hour-ft.^{2}—oR4), and is the heat transfer rate (Btu/hour) (oR). For the third component, photovoltaic cells are used (Fig. 6.3). When sunlight strikes photovoltaic cells, the electron loses its atom instantaneously. The photovoltaic cell has both a positive and negative side, making it a medium that flows through and generates energy. Solar panels are only capable of producing DC power. The circuitry, which consists of a diode and a regulator, stores DC power straight into batteries. Converting the DC power supply to an AC power supply is required for AC. Solar Panel frequently makes approximately 12 V and current differs rendering to the size of solar panel.

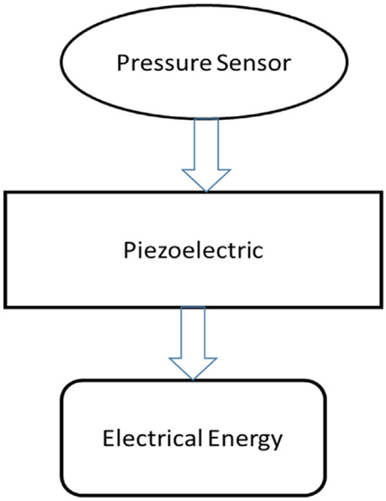

Figure 6.3 Working piezoelectric sensors.

The equation represents the solar power energy calculation

$$\begin{aligned}
&\mathrm{EG} = \mathrm{Area} \times n \times \mathrm{Av} \times \mathrm{PR}\\
&\mathrm{EG} = \mathrm{Energy(kWh)}\\
&\mathrm{Area} = \text{Total solar panel Area}\left(\mathrm{m}^2\right)\\
&n = \text{solar panel yield}\\
&\mathrm{Av} = \text{Annual average solar radiation on tilted panels}\\
&\mathrm{PR} = \text{Performance ratio, coefficient for losses}
\end{aligned}$$

Fusion AI

AI = LSTM + Recurrent neural network (RNN)

Step 1: Computer the flow of the charging station in terms of storage capacity

Step 2: Determine each storage of charging time slot basis.

Step 3: Define the capacity of the storage specified the time slot

Step 4: Recalculate the illustration's exciting flow by the situation of the highervolume boundary charging stations.

The algorithm has reached its decision.

Because the information on the network link is fully understood, can the problems described above solve optimization of LSTM and RNN Only? Sensors, on the other hand, are prone to malfunctions in the existing IIoT [44] energy network. Loss occurs throughout the transmission procedure as well. As a result, when network information is lacking, it is more feasible to optimize storage allocation algorithms and to route policies together. Another example is that we must plan ahead of time for storage allocation and routing. The only solution for all-electric devicesin the IIoT is to provide RES data. Some future Industry 4.0 and 5.0 bus routing maps for IIoT [45] can be appropriately anticipated from the company's database of Industry 4.0, but buses cannot follow the schedule due to the variety of industry working. This problem cannot be solved in this regard since future network information cannot be obtained. These two types of practical cases are more difficult for existing algorithms. We must take other processes to improve our proposed algorithms to meet our initial goals of maximizing overall energy flow from power generating units to destinations. We will focus our attention on a program controller unaware of industry workingflows in the following sections. Instead, we suppose that the controller calculates industryquantities based on past data.

Furthermore, some of the core nodes can make distributive observations and judgments. We can employ predictive algorithms in some significant schedule controllers to learn industry sensorworking and take historical information. By analyzing these characteristics, the IIoT industry RES pattern [46] is eventually established, and the Industry working may then be projected. Earlier estimation approaches, such as random forest, decision tree, Support vector regression, were all based on IIoT industry RES flow assumptions with unique characteristics. This research provides LSTM and RNN as our training model and compares it to traditional approaches. Because LSTM and RNN can remember historical information while forgetting certain useless historical information in IIoT industry RES forecasting, it is our key prediction. The LSTM and RNN model design adapt to different IIoT industry RES flow features or uniform resource flow prediction. In comparison to the previous IIoT industry RES, we discovered that LSTM and RNN could recognize changing patterns more precisely. we will give a brief introduction for LSTM and RNN model as the background knowledge.

Fig. 6.4: The input layer, LSTM Layer, layer, and output layer are all fully coupled in the LSTM NN topology. For every forecast iteration, y_t is the new expected column sequence value $\{r^1{}_t, r^2{}_t, \ldots, x_t\}$.

Joint optimization of LSTM and RNN prediction The purpose of incomplete data is to increase the network's energy transmission efficiency [47]. Calculating the stochastic network dynamic storage allocation in advance for each charging station is a critical aspect of the solution. To accomplish this, we create an optimizer whose structure. We first take the

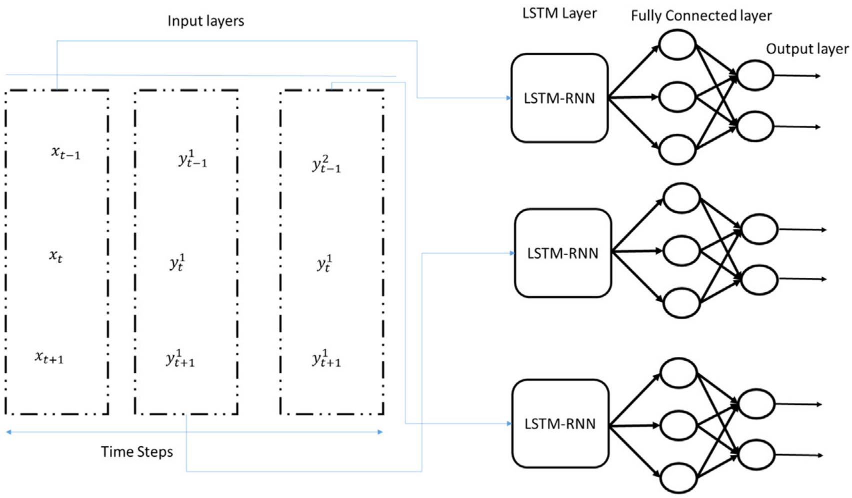

Figure 6.4 Fusion model (long short-term memory-recurrent neural network).

past forecast data as training samples and the historical data of its nearby connections, train the LSTM and RNN model, and then use the learned model to complete and anticipate the IIoT network's missing data. In order to solve the routing and storage optimizing joint problem, this approach simplifies the situation if all of the information is available. After acquiring the dynamic storage allocation and routing system through joint optimization, we apply this result to the genuine IIoT network with missing data. Depicts the method of determining dynamic storage allocation for each charging station. Within the incomplete network, IIoT working flows are separated [48] into different segments. Each section includes the energy resource we wish to predict as well as its nearby energy resource [49]. For each part, we generate an LSTM model. On each section. The missing traffic flow is enabled by using regression to train the LSTM RNN. The network can be reached with complete information by combining a genuine, unfilled network with predicted sensor energy resource [50]. Finally, each charging station has the ability to deploy storage allocations that vary over time. It is compared to the desired result and sent to the LSTM model as feedback. The practice is repeated until the performance improvement is no longer a barrier and the learning notion is strengthened. Understanding the dynamic storage allocation in equates to knowing the storage connection capacity so that the maximum amount of energy can be created by utilizing the maximum flow algorithm from the power station.

6.6 Results analysis

We evaluate different AI algorithms on different IIoT based datasets. Dissimilar assessment metrics were used to examine the goodness of the AI-based model, such as mean absolute error, mean absolute percent error, mean squared error, and root mean squared logarithmic error. We similarly selected the state-of-the-art models for the assessment through the proposed Fusion AI-based model.

6.6.1 Mean absolute error

The mean absolute error (MAE) characterizes the alteration among the original and predictable values and is mined as the dataset's total alteration mean.

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|Y_i - \hat{Y}_i\right|$$

6.6.2 Mean squared error

The mean squared error (MSE) is the alteration between the original value and the predictable value. It is mined by forming the mean formed error of the dataset.

$$\mathrm{MSE} = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2$$

6.6.3 Root mean squared logarithmic error

The root mean squared logarithmic error (RMSLE).

$$\mathrm{RMSLE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\log(\hat{y}_i + 1) - \log(y_i + 1)\right)^2}$$

6.6.4 Mean absolute percent error

The mean absolute percent error (MAPE) is theamount of the accuracy of a prediction. It measures the size of the error (Fig. 6.5; Table 6.1).

$$\mathrm{MAPE} = \frac{\sum \frac{|A - F|}{A} \times 100}{N}$$

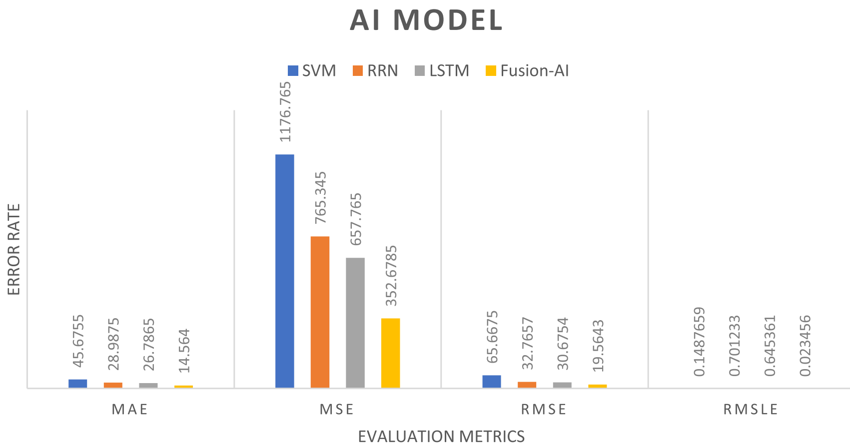

Figure 6.5 Comparative analysis in term of accuracy.

Table 6.1 Evaluation metrics.

Model name	MAE	MSE	Root mean square error	RMSLE
Support Vector Machines (SVM)	45.6755	1176.765	65.6675	0.1487659
Recurrent Neural Network (RNN)	28.9875	765.345	32.7657	0.701233
Long Short-term Memory (LSTM)	26.7865	657.765	30.6754	0.645361
Fusion Artificial Intelligence	14.564	352.6785	19.5643	0.023456

6.7 Conclusion

The IIoT Model Using Fusion-AI of RES has played a significant role in transformingRenewable Energy in this research. IoT digitization improves the efficiency, reliability, resilience, security, and sustainability of electricity grids by increasing accountability forreducing energy waste, saving money, and improving efficiency, dependability, resilience, security, and sustainability. A detailed evaluation of the technical parameters of IoT sensors for the intelligent IIoT scenario was also presented in this research. The customer's value in the energy context comprises safety and reliability and crucial elements such as interoperability and resilience. Power electronics, which plays an essential role in power flow and stability, is one of the two key technology considerations.

In contrast, software, electronics, and embedded systems are primarily used for automation. The systems' major features include customer experience, uncertainty, and the growth of autonomy. The IoT has significantly increased the utilization of renewable energy sources. Power companies to provide a steady supply of electricity to their citizens now use renewable energy. Solar and wind energy usage have already surged because of the IoT. Its use in geothermal, biogas, and hydropower plants should be investigated. Renewable energy is, without a doubt, the way of the future. They will gradually, but unmistakably, meet our rising electrical need.

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