Soft computing and IoT based solar tracker

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ABSTRACT

The significance of the solar energy is to intensify the effectiveness of the Solar Panel with the use of a primordial solar tracking system. Here we propounded a solar positioning system with the use of the global positioning system (GPS) , artificial neural network (ANN) and image processing (IP) . The azimuth angle of the sun is evaluated using GPS which provide latitude, date, longitude and time. The image processing used to find sun image through which centroid of sun is calculated and finally by comparing the centroid of sun with GPS quadrate to achieve optimum tracking point. Weather conditions and situation observed through AI decision making with the help of IP algorithms. The presented advance adaptation is analyzed and established via experimental effects which might be made available on the memory of the cloud carrier for systematization. The proposed system improve power gain by 59.21% and 10.32% compare to stable system (SS) and two-axis solar following system (TASF) respectively. The reduced tracking error of IoT based Two-axis solar following system (IoT-TASF) reduces their azimuth angle error by 0.20 degree.

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1. INTRODUCTION

The insufficiency within the supply of electricity and hasty urbanization everywhere the planet has imposed to find for different sources of power generation. Energy from sun is one among the foremost widespread as well as consistent source to harness energy as it enormously exists and may become a probable supernumerary to various fuels like fossil [1]. With the change in position; there is variation of solar power also, therefore site selection is one of the priority tasks for power plant which is harnessing power from Sun [2].

These days, renewable expansion has efficiently grabbed worldwide attention in the energy production. The three main factors are responsible for their importance stated as: continuous booming consumption of global nonrenewable resources, limitation of the fossil fuels reserves and to control environmental pollution. Approximately India has high potential 300 day of clear and sunny sky because of that we can easily minimize fossil fuel consumption. The National Institute of Solar Energy (NISE) and the highest level of the Ministry of New & Renewable Energy (MNRE) have estimated that the country's solar energy is about 750 GWp [3]. However, India recently reached a grid connected solar energy of about 36.62 GW till October 31, 2020 [4]

and various Indian state power generation capacities is analysis given in Figure 1.

Solar PV systems are considered to be an important energy source and can produce clean energy. Solar trackers have become an important component of solar PV installations. Their ability to track the changing position of the sun in the sky can dramatically boost the energy gain of photovoltaic (PV) two-axis systems by 25 to 45% [5]. This increase is enough to make a viable preposition despite the enhancement in system cost. Trackers make PV panel to follow the movement of sun. These trackers are required to vary their orientation according to sun's position; so more energy can be harnessed [6] .

In solar frameworks, trackers help limit the point of occurrence (the point that a beam of light makes with a line opposite to the surface) between the approaching light and the panel, which expands the measure of energy; hence the establishment produces. Concentrated sun powered photovoltaic and concentrated sun oriented warm have optics that straightforwardly acknowledge daylight, so sunlight-based trackers should be calculated effectively to gather energy. All concentrated solar frameworks have trackers on the grounds that the frameworks don't create energy except if coordinated accurately towards the Sun [7] .
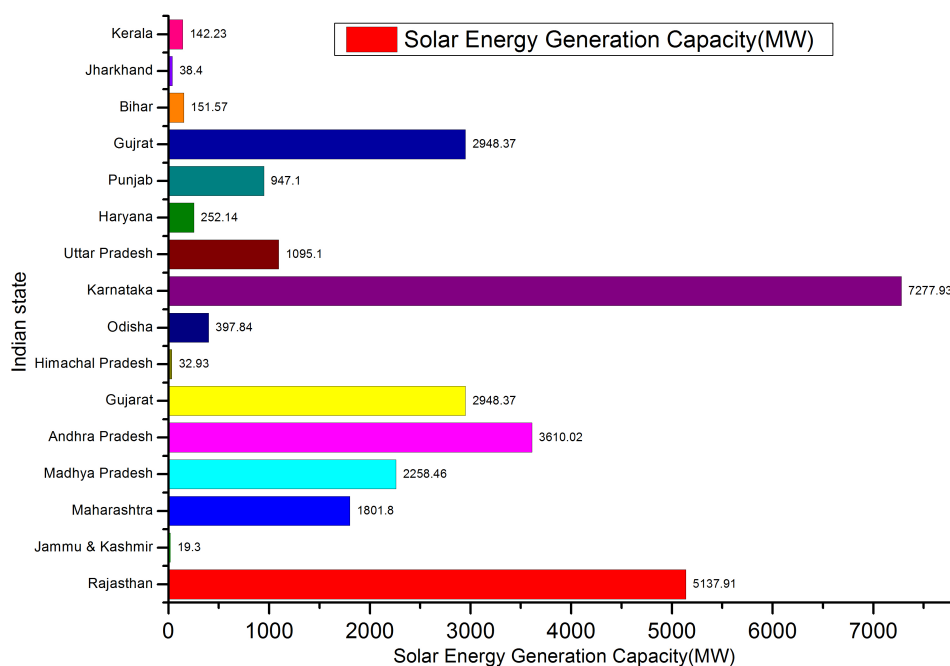

Figure 1. State wise Power generation

Choosing a sun-based tracker relies upon framework size, rates of electric, land limitations, government motivations, scope and climate. Single-hub sun-based trackers turn on one pivot moving to and fro a solitary way. Various sorts of single-pivot trackers incorporate flat, vertical, shifted, and polar adjusted, which turn as the names infer. Double hub trackers constantly point towards the sun since they can move in two unique ways. Types incorporate tip-slant and azimuth-height. Double hub trackers are ordinarily used to situate a mirror and divert daylight along a fixed hub towards a fixed beneficiary. Since these sun trackers track the position of sun vertically and on a level plane, they help acquire greatest sun oriented energy age [8].

There are additionally a few strategies for driving sunlight-based trackers. Latent or passive trackers [9] move from a packed gas liquid headed aside or the other. Engines and stuff prepare direct dynamic sun-oriented trackers by methods for a regulator that reacts to the sun's position. At last, a sequential tracker neutralizes the Earth's revolution by turning the other way. The utilization of sun powered trackers can build power creation by around 1/3, and some case by however much 40% in certain areas, contrasted with panel at a fixed point. In any sun-based application, the change effectiveness is improved when the panels are ceaselessly acclimated to the ideal point as the path of sun crosses the sky. As improved effectiveness implies improved yield, utilization of trackers might have a serious effect to the pay from a huge plant. This is the reason utility-scale sun-based establishments are progressively being fixed on global positioning frameworks.

There are, be that as it may, a few weaknesses of sun powered trackers. Adding a sun oriented global positioning framework [10] implies added greater hardware, rotating parts and cog wheels, that will necessitate standard upkeep and fix or substitution of broken parts. Additionally, if the sun-based tracker framework separates when the sunlight-based panel are at a limit point, the deficiency of module until the framework is useful again can be large. A sun-oriented tracker is additionally more inclined to be harmed in a tempest than the solar modules.

In A. A. Sneineh and W. A. Salah [11] designed a low cost, high efficient and flexible solar follower to improve power generation. The intended two-axis closed-loop (CL) solar tracker constitutes efficient structurer using microcontroller, H-Bridge driver and photo-sensors. The designed System accomplish the seized of 40% more energy compare to fixed PV system. Mohaimin *et al.* designed a low power PV system [12] and compare their observation on the basis of external or self-power. The author observes that two-axis self-powered system reduce 18% respect to external power two-axis system. Nearly 82.5% of energy is consumed by low internal powered two-axis PV system whereas they produce only 10%. In case of single-axis the consumption is 31.7% & and they produce only 5 to 9%. This concludes to avoid the use of low power PV panel so that power production can be maximised. Chan and Zalani [13] develop an Arduino microcontroller based sensor less two-axis solar follower. Global and local search algorithm is used by microcontroller prove 17.96% improved power compare to fixed panel system & azimuth angle error reduce by 3%.

The main idea of the project is to set up a monitoring system with the most economical and precise solar coordinates for maximum efficiency. As we know concentrated photovoltaic (CPV) panels are of greater efficient due to the fact that they use optics to concentrate huge amount of sun radiation on the photovoltaic panel to generate more electricity than conventional PV [14] panels. The design and performance of the solar positioning system are suggested based on camera-captured images. Such images implemented with DIP to measure the sun azimuth angle using GPS [15] and artificial neural network. These features are sent to the microcontroller using IoT [16] to get the precise location of sun coordinate for maximum energy. The proposed method can reduce the dependence of tracking by LDR which easily effected by electric discharge of adverse weather. This also fined solution for cloudy weather by image based tracking [17] and ANN based weather forecasting [18].

2. OBJECTIVE OF THE WORK

The foremost idea of the paper is stated below the system use GPS [19], ANN [20] and DIP [21] to solve the problem generally occur in solar tracker:

- DIP based-feed-forward solar following system.
- AI forecasting solar module output than DIP algorithm approximating the control of tracking.
- The outcome of panel continuously surveillance through IoT.
- Provide Economical solution.

3. RESEARCH METHOD

Arduino board is a micro controller which is based on Integrated Development Environment (IDE) software. It is central processor and a 32-bit Intel Pentium-elegance system dependable on a chip (data sheet). Its mainframe is based on Intel structure which is designed to operate hardware. All software needs pin-adaptable with Arduino shields manufactured for Uno R3. Arduino [22] board is manufactured to assist the shields rushing on 3.3V or 5V.

Because of this; real time information of the sun is grabbed by a digital sensor & GSM, Arduino Uno backing cloud computing with Wi-Fi supporting mini PCIs slots. It will feed to an IOT based solar monitoring device so we can easily connect all the sensors. The algorithm based on MPPT with the LDR sensors are placed in "Thingspeak" virtual storage and this information is put to use for the recordings of sun pictures at different time portals throughout the day. The selected tools used in this work are Internet protocol algorithms, artificial intelligent techniques and the equipment application software required for monitoring and controlling the panels for maximum effectiveness and affordability. The live monitoring of the sun is done by a vision camera whose rotations can be done by servo motor mechanism. The azimuth angle, latitude, longitude and the altitude can be observed with the help of live GPS coordinates. The readings and algorithm obtained from this will be facilitated using IoT and micro controller for automation of sun tracking.

3.1. Materials and Methods

The tracking system consists of DIP, ANN, GPS and AI machines used by the operating system for tracking and fruitful energy gain. The tracking is done by image sensors which operate the servo motors assembly shown in Figures 2 and 3. Azimuth angle determines elevation of the panels to track the sun. In Figure 4 Sun RGB image is processed to convert into gray image . In our work we don't consider the RGB image because it's DIP will take more processing time because of its three co-ordinates or RGB image. The gray image is of two co-ordinates and digitally represent as 0 or 1. The gray image DIP time is less as compared to RGB image.
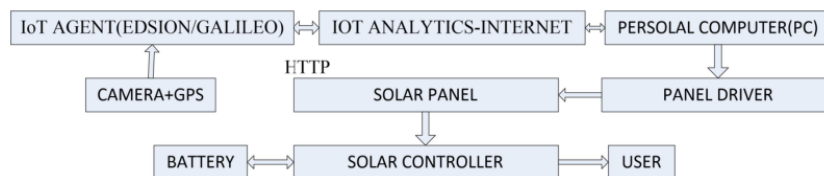

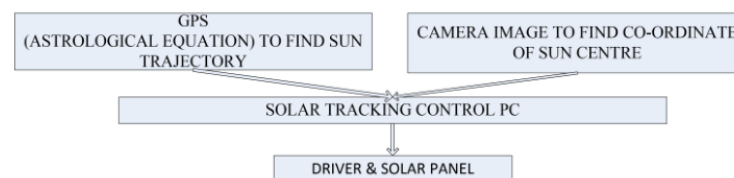Figure 2. Solar following system process using IOT

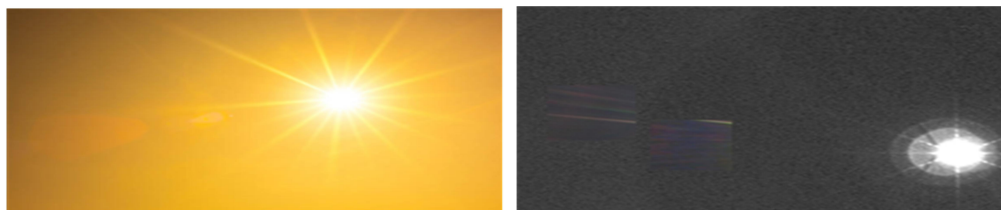Figure 3. Sun image by IOT solar following system

Figure 4. Normal & their gray scale sun image by Iot based solar follower DIP techniques

Image process could be a methodology to accomplish some procedures on a picture, so as to induce an increased image or to excerpt some helpful data from it. It is a sort of signal process within which input is a picture and output could also be image related to that picture.

3.2. Digital image processing

DIP uses a digital computer to process the digital images through required algorithm. It permits a wide range of algorithms to be inserting as input data and it keeps away the problems such as noise and distortion throughout the process. In order to make the machine optimum, DIP techniques have been established and thrived. Accurate and precise tracking is the basic requirement for which the DIP control techniques is implemented on sun image which helps to track the sun. It deals with conversion, acquisition and processing of images. The step of method is preprocessing, extraction of features [23] and selection of transforming the data. This will be more effortlessly and constructively processed for the purpose of classification, and recognition.

Pre-processing - Pre-processing is a familiar name for operation with images at the lowest level of abstraction having both input and output is intensity images. Preprocessing develops the image data that suppress admissible distortions. It intensifies some image features pertinent for additional processing and analysis tasks. Pre-processing techniques consist of cropping, filtering, intensity-adjustment, histogram-equalization [24], brightness thresholding, clearing areas of a binary image, and detecting edges.

Image smoothing filters - Smoothing reduces noise within an image [25]. It is a key technology in image enhancement which removes noise from the image. So, it is an essential functional of image-processing tool to perform within spatial co-ordinate and frequency. It consists of the Gaussian, median, mean, maximum, minimum, non- local means, percentile and rank filters. These can be applied to reduce the noise in the image so they must be used with care without altering the important information within the image. Smoothing filters are used for removing blurring from the image using linear and non-linear filters. Other kinds of filters are sobel, directional mask, and prewitt.

3.3. Wavelet transformation

The principle of high frequency detail of digital image is edge. Conventional filters remove noise ineffectively and so it is require to removing the noise without altering the edges. Wavelet application pinpoints the suitable frequency band setting apart by indicator's oneness. After that the frequency band equivalents the spectrum which amplifies the decision. Wavelet Transform visibly removes image noise. It works on various scales and it scrutinized the de-noising as hard and soft thresholding based on orthogonal Wavelet Transform [26]. Edge spotting and Noise suppression of the image is demised by a wavelet transform using Matlab tool.

3.4. GPS System

GPS represent global positioning system can find longitude, time and latitude positions are used to establish zenith and azimuth angle of the sun. The GPS uses astronomical equation to establish and estimation of trajectory of the Sun following system. The two basic astronomical equation used here are declination angle (ASD) and the time equation (TEQ). Fractional year (φ) is estimated in radians given by (1).

$$\varphi = \frac{2\Pi}{365}\left[(YD-1)\frac{(hour-12)}{24}\right] \tag{1}$$

Where YD is Year's Day. In leap-years 366 is use in place of 365 in (1). Fractional year (φ) is used to calculate Time equation (TEQ in minute) and angle of Sun declination (ASD in radian) is expressed as shown in (2) and (3) respectively.

$$TEQ = 229.18(0.000075 + 0.001868\cos\varphi - 0.032077\sin\varphi - 0.014615\cos 2\varphi - 0.040849\sin 2\varphi \tag{2}$$

$$ASD = 0.006918 - 0.399912\cos\varphi + 0.070257\sin\varphi - 0.006758\cos 2\varphi + 0.000907\sin 2\varphi \tag{3}$$

The offset time (OFT) calculated in minutes given by (4).

$$OFT = TEQ + 4 \times longitude - 60 \times ZonalTime \tag{4}$$

Where Indian Standard time (IST) = Zonal time having time offset of UTC +05:30. True Solar time (TST) is derived by (5).

$$TST = HR \times 60 + MIN + (SEC \div 60) + OFT \tag{5}$$

Where HR – 0 to 23 hour, MIN – 0 to 59 minute, SEC – 0 to 59 second, HA - Hour angle (degree) of Sun & LAT = Latitude angle. Hour angle is estimated by (6).

$$HA = (\frac{TST}{4}) - 180 \tag{6}$$

Sun zenith angle (ψ) is calculated by using HA, latitude & ASD represented by (7).

$$\cos\psi = \sin LAT\sin ASD + \cos LAT\cos ASD\cos HA \tag{7}$$

Sun azimuth angle (η, degree clockwise from north) is given by (8).

$$\sin(180 - \eta) = \frac{\sin LAT\cos\psi - \sin ASD}{\cos LAT\sin\psi} \tag{8}$$

3.5. Artificial intelligent (AI) classification technique

Neural network diagram is shown in Figure 5 having multilayer perceptron with input, hidden and output layer. The input layer involves predictable vector values (X1...Xp) and bias of 0.1 which normalize within -1 to 1 span given to each node of hidden layer. The weight is given to a transfer function and output as hj. The hidden layer outputs are fed to the output layer nodes which are multiplied by a weight and the resultant weight are sum together to generating the output vj at the outer layer. 'y' is the actual value from the neural network.

4. RESULT AND DISCUSSION

The proposed project is based on an ANN method for determining the maximum power from the photovoltaic panel is simulated on MATLAB tool. The ANN is used MPPT algorithm to produce & generate maximum power. The Efficiency of system increase and tracking time reduce with the use of ANN based MPPT. Tracking algorithm is added into Thingspeak cloud through Internet of things platform can be worn in smart home uses. This system has capability to forecast the weather condition as sunny, rainy & cloudy. IOT based algorithm is applied in the solar photovoltaic system to launch the maximum power yield of the solar panels and to sustain the highest photovoltaic energy translation during the partially shaded circumstances. More prominently, the internet of things depresses the monotonous work of visiting sites with repeatedly taping of performance data, therefore increasing the control of isolated areas for efficient and fast troubleshooting and repairs. DIP is the way to do various image processing application with image like de-noising, feature extraction, filtering, contrast stretch etc and give the output as best informative image or the features of the image in frequency form so that ANN get proper image feature for analyzing. The basic DIP steps are: i) pre-processing; ii)enhancement; iii) feature extraction.

4.1. Histogram investigation

The histogram provides us the broad information regarding the image's pixel intensity value and their occurrences rate. Histogram throughout improve the contrast of image so that the image intensity is nearly uniform. Histogram for sunny days is shown in Figure 6 which specifies that rate of high intensity (255) occurrence is maximum compared to rainy or cloudy days. The extracted features from various images of sun are tabulated in Table 1.
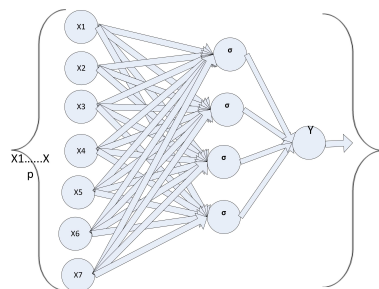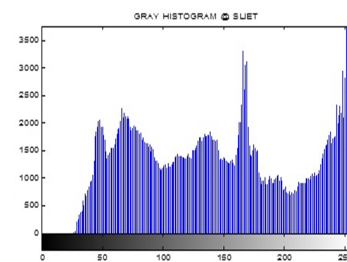

Figure 5. Multilayer perceptron structure

Figure 6. Histogram of sun image

4.2. Classification using ANN

Back propagation artificial neural network (BPN) classification depict maximum power outcome and processed parameters of ANN are tabulated in Table 2, sun azimuth angle precisely near to the target value are shown in Figures 7, 8, 9. Here the BPN power output increase by 15% and error in azimuth angle reduced to 0.20 compare to estimated result. The overall power gain improve to 33% compare to stable solar system.

4.3. Digital sensor

The digital sensor is the camera which helps in communicating between sun location and binary information of sun image. So the feature is extracted from camera picture and ANN proceed further to find exact co-ordinate of sun center and then the instruction given to motor driver to track sun center quadrate. The ssensor is connected to Arduino board through A0 connector.

Table 1. Sun Image Extracted Feature

S.No	Width	Max	Mean
1	70	255	111.49
2	69	255	106.835
3	68	255	106.835

Table 2. Parameter of Artificial Neural Network

S.No.	Characteristic of ANN	Value
1	Total number of input layer nodes	7
2	Total number of hidden layer nodes	4
3	Hidden layer activation function	Sigmoid
4	Total number of output layer nodes	1
5	Output layer activation function	Sigmoid
6	Total number of iterations	204
7	Factor of learning	0.8
8	MSE (Mean Squared Error)	0.0197

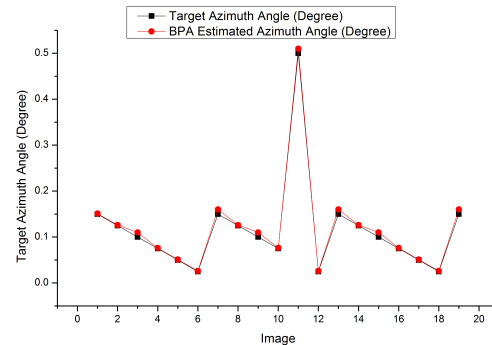Figure 7. Power output comparison of IOT sun following system

Figure 8. Azimuth angle of solar following system

4.4. Experimental observation

Experimental observation analysis of 10 watt stable system (SS), Two-axis solar follower (TASF) and IoT based TASF is given in Table 3 and their graphical representation shown in Figure 9.

Table 3. Experimental observation of 10 watt SS, TASF and IoT based TASF

Readings	SS-Voltage (V)	SS-Current (A)	SS-Power (W)	TASF-Voltage (V)	TASF-Current (A)	TASF-Power (W)	IoT TASF-Voltage (V)	IoT TASF-Current (A)	IoT TASF-Power (W)
1	0.031	0	0	0.0318	0	0	0.0319	0	0
2	1.031	0.49	0.50519	0.4134	0.018	0.007441	0.4147	0.0198	0.008211
3	3.131	0.051	0.159681	3.975	0.09	0.35775	3.9875	0.099	0.394763
4	3.472	0.102	0.354144	4.611	0.18	0.82998	4.6255	0.198	0.915849
5	3.782	0.119	0.450058	5.7876	0.162	0.937591	5.8058	0.1782	1.034594
6	11.532	0.2924	3.3719568	12.6564	0.351	4.442396	12.6962	0.3861	4.902003
7	16.647	0.425	7.074975	17.62038	0.495	8.722088	17.67579	0.5445	9.624468
8	17.05	0.4709	8.028845	17.649	0.4986	8.799791	17.7045	0.54846	9.71021
9	16.74	0.4471	7.484454	17.6172	0.5004	8.815647	17.6726	0.55044	9.727706
10	13.113	0.3179	4.1686227	17.6172	0.5004	8.815647	17.6726	0.55044	9.727706
11	5.363	0.255	1.367565	14.7552	0.342	5.046278	14.8016	0.3762	5.568362
12	1.8383	0.068	0.1250044	5.9466	0.162	0.963349	5.9653	0.1782	1.063016
13	0.031	0	0	1.8126	0.054	0.09788	1.8183	0.0594	0.108007
Average value	7.212408	0.233715	2.54542276	9.268722	0.257954	3.67968	9.297868	0.283749	4.060376

The average panel output efficiency is given by (9). P1-Power output by stable panel P2-Power output by TASF P3-Power output by IoT based TASF

$$\eta_{Avg} = \frac{\Sigma(P_X - P_y)}{P_y} \times 100 \qquad (9)$$

So compare to stable system (SS) the increased efficiency of IoT based TASF is given by (10).

$$\eta_{Avg(IoT-SS)} = \frac{\Sigma(4.06 - 2.55)}{2.55} \times 100 = 59.21\%$$ (10)

Respect to TASF, IoT TASF increased efficiency is given by (11).

$$\eta_{Avg(IoT-TASF)} = \frac{\Sigma(4.06 - 3.68)}{3.68} \times 100 = 10.32\%$$ (11)
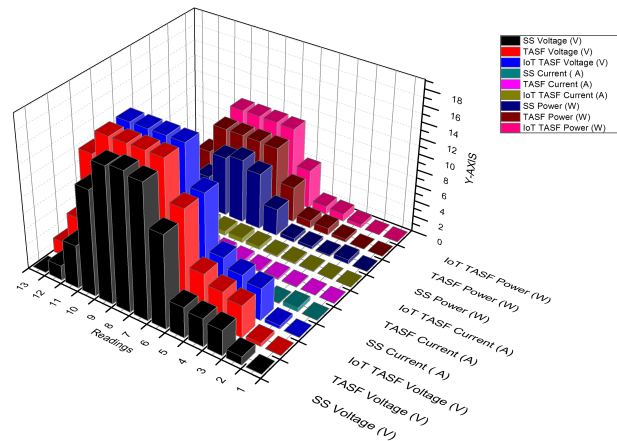

Figure 9. Comparison SS, TASF and IoT TASF parameter

5.   CONCLUSION

A modernized way to deal with building up a scholarly classifier to investigate and control the following capacity of the sunlight based board is effectively reenacted. The back propagation (BPA) classifier is vibrant when synchronized with other traditionalist classifiers. The objective fulfillment for the planned classifier articulated that the proposed innovation had the option to summon all the pictures of the sun at different tendencies with accuracy whose values are 1 individually. Thus a smart feed forward controller for following the sun's situation with regard to azimuth point is made conceivable by the picture investigation. Besides, the power generation is dependable at most on high intercity of light generation. Thus information of sun's picture is used to estimate the output power. GPS and ANN-DIP system having reduced azimuth angle error of 0.20°with increase in efficiency nearly 59.21% compare to SS and 10.32% compare to TASF. The significant thought behind this examination is to distinguish the unfavorable condition force age conditions during shady and blustery days. The online monitoring of output is possible because of IoT. In future this system (GPS+DIP+BPN+IOT) will be fruitfully implemented in solar farming, where a single online system or computer can handle large number of solar tracker which reduces cost of individual PV panel tracking system. This mechanization technique gives various quantifiable boundaries to the sun position in order to get the greatest yield.

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