International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 12 | December - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

The Use of Artificial Intelligent Applications in Electrical Power Distribution and Automation Control System

Praveen Kumar Sharma[1], Anjana Tiwari [2]

[1] Research Scholar, University of Technology, Jaipur, Rajasthan, India,
Email: Praveenprem.sharma@gmail.com

[2] Professor Department of Electrical Engineering, LIET College ,AlwarRajasthan, India, Email: tiwarianjana594@gmail.com

Abstract

Artificial intelligence has provided great potential and space for the optimization of electrical engineering and it will bring about great improvement not only in economic aspect but also in safety and actual operation control. Since the advent of artificial intelligence it has been widely applied in all fields of life and achieved notable application effect its emergence has even pointed out the direction for the development of many fields and the field of electrical automation control is no exception. In reality, the application of artificial intelligence technology has greatly promoted the progress of the concrete practice of electrical automation and should be paid full attention to by related enterprises and staff. This paper aims to summarize the emergence and development of artificial intelligence and its components and finally summarize the advantages and functions of artificial intelligence in electrical automation control.

Advances in machine learning and artificial intelligence (AI) techniques bring new opportunities to numerous intractable tasks for operation and control in modern electric distribution systems. Revolving around the characteristics of distribution system operation and integration of distributed energy resources this paper also illuminates prospects and challenges typified by the privacy explain ability and interpretability of such AI applications in smart grids.

KEYWORDS: - Distribution systems, smart buildings, neural networks, Artificial Intelligence, Electrical Engineering, ***power systems.***

1. INTRODUCTION

With the development of science and technology artificial intelligence and electrical automation control technology is innovating and developing. The application of artificial intelligence technology in the electrical automation control is more and more extensive which provides the development of automation control technology a solid foundation and strong support. In this paper artificial intelligence is introduced with their research directions including expert system machine learning pattern recognition artificial neural network and deep learning etc. This paper aims to summarize the emergence and development of artificial intelligence and its components and finally summarize the advantages and functions of artificial intelligence in electrical automation control

The deployment of advanced metering infrastructure integrated with the Internet of things has transformed the traditional CPDSs. Smart meters pharos measurement units smart appliances, and smart plugs enable the collection of various data while advanced IoT architecture allows for fast and accurate data transmission for system monitoring More specially distribution systems are distinguished from traditional transmission systems due to higher ratio multi phase unbalanced operation limited sensor installation poor observeabilityandfrequenttopologychanges.Nonethelessthetraditionalmethods most of which are originally developed for transmission systems struggle to address such challenges As such it is crucial to deploy techniques that are capable of processing monitoring and utilizing historical and real-time data of large volume dimension and heterogeneity.

2. Artificial Intelligence in Automations control system

Expert System

An expert system (ES) is a software system that captures human expertise for supporting decision making this is useful for dealing with problems involving incomplete information or large amounts of complex knowledge .Expert systems are particularly useful for online operations in the control field because they incorporate symbolic and rule based knowledge that relate situation and actions and they also have the ability to explain and justify a line of reasoning. The ES basically consists of knowledge base database reasoning machine interpretation mechanism knowledge acquisition and user interface which is shown in Figure 1.

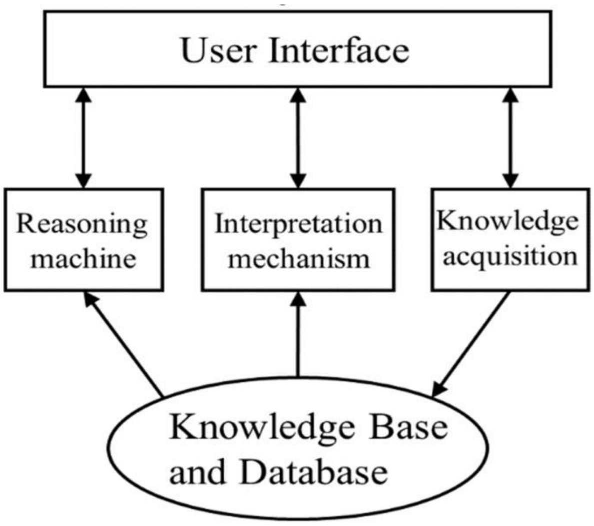


Figure 1 The sketches of the expert system

Machine Learning

Machine Learning (ML) which mainly focuses on how the computer simulates human learning behavior reorganizes the existing knowledge structure with the knowledge and skills learned and continuously improve its performance. Machine learning techniques are often adopted for addressing the knowledge acquisition (KA) bottleneck in implementing expert systems. The KA bottleneck arises due to the fact that experts are better at collecting and archiving cases than in expressing their experience and encountered cases explicitly into production rules. In using machine intelligence techniques to tackle this bottleneck knowledge is automatically extracted from data. Symbolic information can be integrated into an artificial neural network learning algorithm and the learning system supports knowledge modeling and extraction

Neural Network

The artificial neural networks (ANN) approach involves a nonlinear mapping between input and outputs which consist of interconnected neurons arranged in layers. The layers are connected so that the signals at the input layers of the neural network are propagated throughout the network .In the process industries ANNs have been applied for fault detection and diagnosis. For example Cubicles and Lima described an adaptive hybrid system built upon prior knowledge and neural networks to model process control strategies and uncertain parameters in a highly non linear CSTR and a four stage floatation unit.

3. Advantage of Artificial Intelligence on Electrical Automation Control

(1) The traditional classical controller often needs to design according to the controlled object model but the model construction will usually have many uncertain factors such as changing of parameters and the numerical type so that to make the design more difficult. Artificial intelligence control is not difficult and the AI function approximate does not need to control the model of the object

(2)Performance enhancement by properly adjusting related parameters performance can be improved quickly. For example, the fuzzy logic controller reacts faster than the optimal PID controller and the overshoot is smaller

(3) More convenient to use. The artificial intelligence controller is easier to adjust than the classical controller, and is more adaptable to new data or new information

4. Application of Artificial Intelligence in Electrical Automation Control

In Electrical Equipment

Artificial intelligence is first reflected in the electrical design for electrical automation control. As we all know the electrical equipment structure is complex. In the actual design process it not only needs to use the electronics circuits electromagnetic fields motors automation and other disciplines related knowledge but also needs to understand the generators sensors and other components of the role and mechanism and it has high requirements for the designer's professional level and work experience and thus electrical equipment design is a complex project. In the operation of electrical automation equipment the operation of the electrification system is a very complicated problem involves a lot of disciplines and fields. Its operation and control requirements requires a high degree of knowledge reserves and higher quality

In Electrical Control

Artificial intelligence in the development of the automation not only can promote the overall progress in the field of electrical automation control more to promote the development of automatic control of progress so in the field of electrical automation control innovation needs the support of artificial intelligence using artificial intelligence technology to improve human consciousness ofmechanical ability strengthen the electrical automatic control In addition, the failure of the power system of will be ruled out promoting the development of the artificial intelligence technology in constant forward carving out a new direction in electrical automation control through the theory of all aspects of application of intelligent technology making the people's living standards continue to improve.

In Fault Diagnosis

In general artificial intelligence based fault diagnosis techniques include rule based reasoning (RBR) case-based reasoning (CBR) and fault-based tree fault diagnosis. Based on the basic composition and basic principle of the traditional expert system a mechanical fault diagnosis expert system based on RBR and CBR reasoning is constructed. The overall structure is shown in Figure 2. Electrical equipment once appear problem its symptom and the practical problems of its relevance is very complex it is difficult to judge and determine, if the use of artificial intelligence system is solved this difficult problem. Already using artificial intelligence technology to judge fault system are fuzzy logic expert system and neural network. In power system the transformer is very common and popular also has a lot of research about it. At present mainly through decomposition of gas in the transformer oil for transformer fault diagnosis

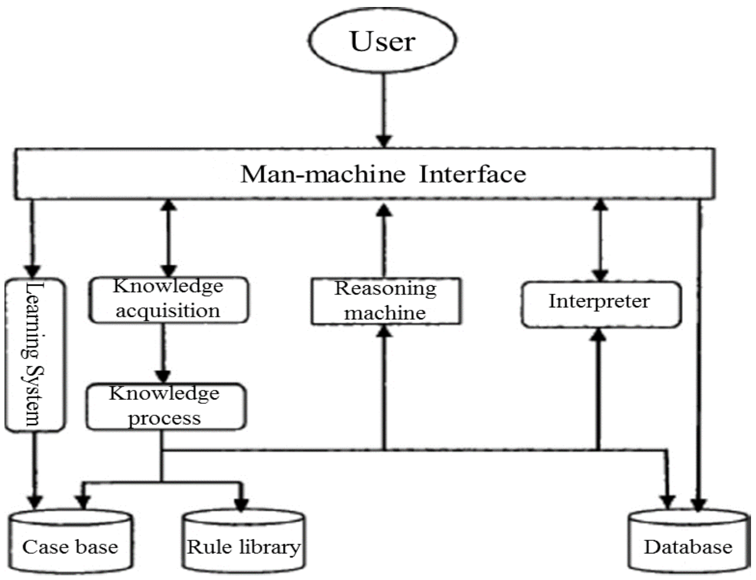


Figure 2 overall structure of the system

5. Artificial Intelligence in Distribution system

Among the massive and rapid development of AI techniques that benefit from the availability of large datasets and increased computational power in recent years we here introduce several representatives among the latest research progress. Moreover these algorithms are widely explored for power system operation and control in CPDSs including transfer learning (TL) graph learning (GL) deep attention mechanism, deep reinforcement learning (DRL) and physics guided neural networks (PGNN)
Fuzzy logic finds its application in the control of power systems like voltage control, stability control power flow control and stability analysis and enhancement load forecasting and performance improvement of transmission lines

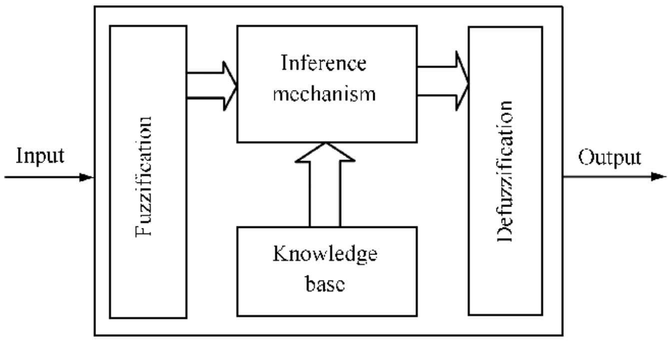


Fig-3: Block diagram of a fuzzy system

Transfer Learning

TLaimstoimprovethelearningofataskinthetargetdomainbyleveragingknowledgegainedbyitslearninginthesourcedomain.Differentiatedfromtraditionalmachinelearning(ML)algorithms,TLiscapableofrepurposingdifferentrelatedtaskstoimprove generalization in another setting without the assumption of the same distributions of trainingandtestingdataTheinstanceweightingstrategyisacommondatabasedTLapproachwheredifferentweightsareassignedtothesourcedomaininstancesoftheloss function based on their usefulness to the target domain task

Graph Learning

In recent years, graph neural networks (GNNs) a subset of GL, have received a surge of interest due to their successinnaturallanguageprocessingandimagerecognitionInparticular,GNNsareclassifiedintofourcate goriesrecurrentGNNconvolutionalGNNgraphautoencoders(GE) and spatial-temporal GNN. Convolution GNN is a generalization of convolution from 2-D input to graphs, while GAE reconstructs graph data from nodes graphs encoded into latent vector space.

Physics Guided Neural Networks

Different types of physics knowledge are incorporated into NN architectures for dedicated applications in power systems such as equation correspondence and network topology for power flow .Furthermore PGNN shows promise in integrating different deep learning techniques as introduced before to overcome the challenges of limited or noisy labeled data and varying operating environments in distribution systems by leveraging physics knowledge to supplement or guide the learning process.

6. Artificial Intelligence Applications in Distribution Systems

Power Flow Analysis

Power flow analysis is fundamental to power system planning monitoring, and control. Approaches that utilize numerical optimizers such as the Newton Rap son (NR) method are conventionally implemented as the solution. Power flow requires meeting load demands while not violating the physical constraints of the system .The problem of achieving the optimal steady state operating point of the system that minimizes the generation cost while being reliable and safe is referred to as the optimal power flow (OPF) problem .The OPF problem is NP hard and some numerical methods are computationally expensive and do not guarantee a global optimum Probabilistic power flow a physics informed graph attention network is adopted for power flow analysis in and theinductivelearningabilityoftheattentionbasedmodelenhancescomputationalefficiency.Byaggregating neighboringinformation selectively through the graph attention-enabled convolution layer captures the complex correlation of wind and solar power generation realizing improved performance in probability power flow calculation.

Volt/VAR Control

Itdeterminesthebestavailablecombinationofsettingsfromcontrollabledevices including on-load tap changers (OLTCs) capacitor banks (CBs) inverter-connected photo voltaic (PVs) voltage regulators, and dispatch able electric vehicles (EVs). Conventionally model based optimization methods such as conic relaxation and mixed integer linear programming are adopted. However not only does DER penetration cause variations in the network topology butitalsointroducesintermittencyanduncertaintyinDERgeneratioThesechangesmightcausesharpfluctuationsinvoltagewhichleadtoserious overvoltage/under voltage issues

Line Parameter Calibration

Besides topology, the operation, control and analysis of distribution systems are also built on accurate model parameters such as line impedance. However, such information is often unavailable incomplete or outdated due to the system upgrade especially in secondary distribution systems. Some utilities only have single line diagrams of their systems without detailed three-phase line parameters; other utilities possess system models but they are often incomplete or outdated due to frequent system expansion and reconfiguration Conventional parameter calibration methods either require the widespread installment of costly sensors such as PMUs or assume a simplified single phase distribution network mode which is not suitable for industrial practice. To overcome these challengeseveralAItechniquesareappliedtosolvetheparametercalibrationproblemforthree-phase distribution lines..

7. Conclusion

With the development of economy electrical automation is also facing new challenges. The traditional manual control has been difficult to adapt to the current social environment. The introduction of artificial intelligence technology has promoted the innovation of electrical automation control which is of great significance to the development of electrical automation. This paper summarizes the components and the applications of artificial intelligence including its application in electrical equipment electrical control and fault diagnosis. At present artificial intelligence technology has been widely used in the field of electrical automation control which has promoted the level of this subject.

However in the specific application process there are still some problems. Therefore relevant technical personnel should continue to study and innovate as to promote the level of application of artificial intelligence technology to achieve innovation and improvement

8. Reference

[1] MH Hassoun. Fundamentals of artificial neural networks [J]. Proceedings of the IEEE

[2] FA Cubillos, EL Lima. Adaptive hybrid neural models for process control [J]. Computers & Chemical Engineering

[3] PF Tsai, JZ Chu, SS Jang, SS Shieh. Developing robust model predictive control architecture through regional knowledge analysis of artificial neural networks [J]. Journal of Process Control

[4] Y Power, PA Bahri. Integration techniques in intelligent operational management: a review [J]. Knowledge-Based System

[5] Y Lecun, Y Bengio, G Hinton. Deep learning [J]. Nature
Nirmal,
D.ArtificialIntelligenceBasedDistributionSystemManagementandControl.J.Electron.

[6] Bhattarai,B.;Paudyal,S.;Luo,Y.;Mohanpurkar,M.;Cheung,K.;Tonkoski,R.;Hovsapian,R.;Myers,K.;Zhang,R.;Zhao,P.;etal. Big Data Analytics in Smart Grids: State-of-the-Art, Challenges, Opportunities, and Future Directions.*IETSmartGrid***2019**

[7] M.A. Hannan, Z.A. Ghani, M.M. Hoque, M.S.H. Lipu, A fuzzy-rule-based PV inverter controller to enhance the quality of solar power supply: Experimental test and validation, Electronics 8 (2019) 1335

[8] IEA,"WorldEnergyOutlook2015,"2015.https://www.iea.org/reports/world-energy-outlook-2015

[9] Nirmal,D.ArtificialIntelligenceBasedDistributionSystemManagementandControl.*J.Electron.* **2020**

Basic Principle of PV Cell

PV cells are essentially a very large area p-n junction diode where such a diode is created by forminga junction between the n-type and p-type regions. As sunlight strikes a PV cell, the incident energy is converted directly into electrical energy. Transmitted light is absorbed within the semiconductor by using the energy to excite free electrons from a low energy status to an unoccupied higher energy level. When a PV cell is illuminated, excess electron-hold pairs are generated by light throughout the material, hence the p-n junction is electrically shorted and current will flow Solar Photovoltaic system cell can be modeled as an ideal current source in parallel with an ideal diode. Fig.1 represents the simplified circuit mode l of a PV cell. The output of the current source is directly proportional to the light falling on the cell (photocurrent I_{ph}). During darkness, the solar cell is not an active device; it works as a diode, i.e. a p-n junction. It produces neither a current nor a voltage. However, if it is connected to an external supply (large voltage) it generated current I called diode(D) current or dark current. The diode determine the I-V characteristics of the cell.

Modelling of Photovoltaic Array

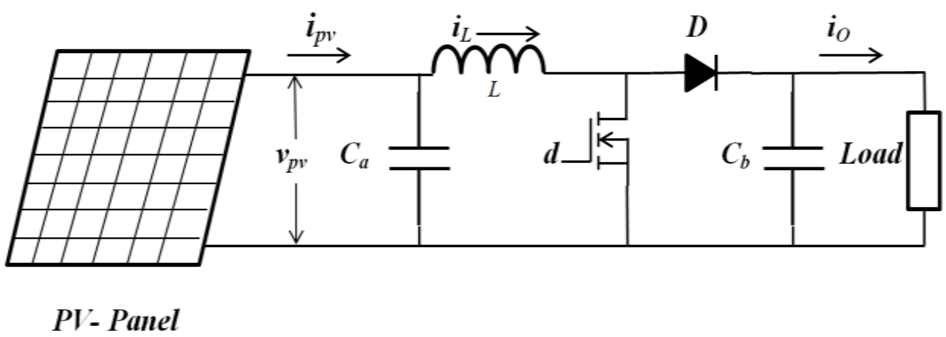


Fig.1Solarpowergenerationsystemwithdc/dc boost converter

Consider a PV panel array composed of solar cells arranged in an np-parallel, ns-series configuration. Let v_{pv} and i_{pv}, respectively, de note the output voltage and current of the PV array. The voltage/current characteristic equation of the PV array can be described by a light-generated current source and a diode .If the internal shunt and series resistances are neglected, the output current of the PV array is given by,

$$I = I_{pv,cell} - I_d \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$I_d = I_{0,cell}[\exp(\frac{qv}{akT}) - 1] \ldots\ldots\ldots\ldots\ldots (2)$$

$$I = I_{pv,cell} - I_{0,cell}[\exp(\frac{qv}{akT}) - 1] \ldots\ldots\ldots(3)$$

A single PV cell produces an output voltage of less than 1 volt, it is necessary to string together a number of PV cells in series to achieve a desired output voltage. Solar panel is a power source having nonlinear internal resistance. As the intensity of light falling on the panel varies, its voltage as well as its internal resistance both varies. To exact maximum power from the panel the load resistance should be equal to the internal resistance of the panel. The solar panel module, whichcontain36cells in series 1sets.

According to this equation, Fig. 2 depicts the characteristics of the array power with respect to the PV voltage, the insulation, and cell temperature. It can be observed that the maximum power point is maximized by the PV voltage and is dependent on various insulation and temperature

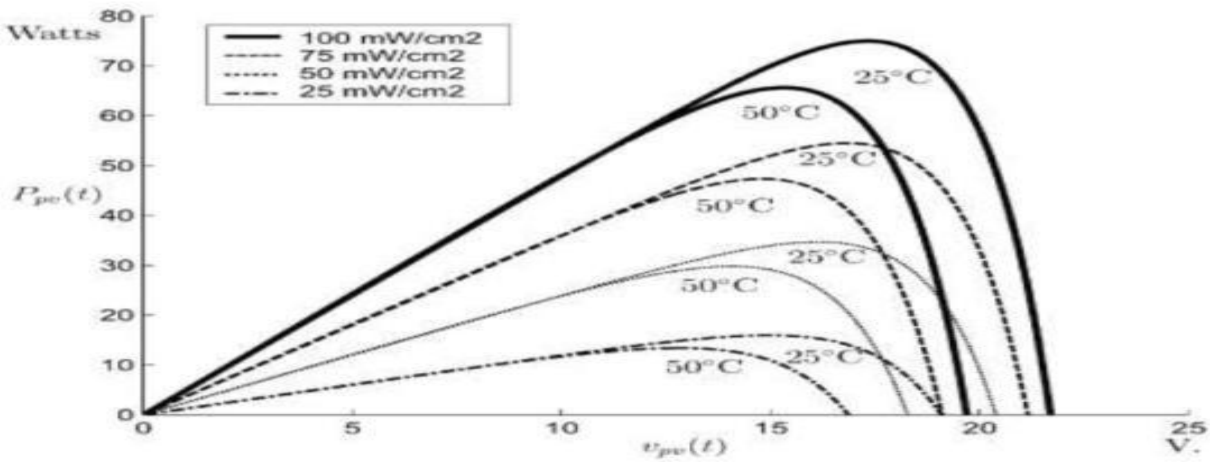


Fig.2Characteristicsofthearraypowerwith respect to the PV voltage

3. Maximum Power Point Tracking

The objective of MPPT is to extract maximum power from the solar panels. The I-V and P-V characteristics of the solar panels are affected by atmospheric changes such in solar irradiance (G),temperature(T)and diode ideality factor (n). Hence the MPPT should track the maximum power from the solar panel subject to these changes.

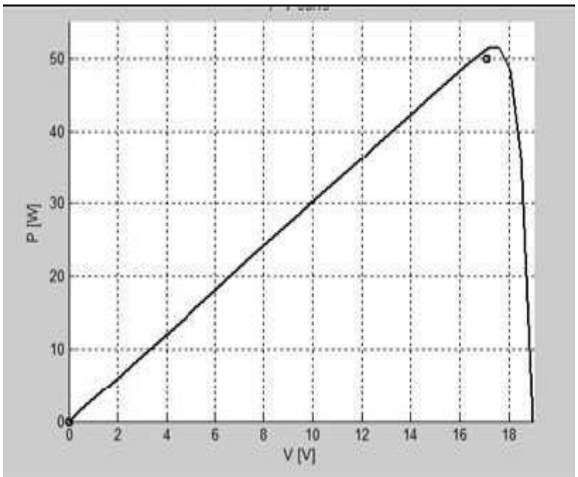
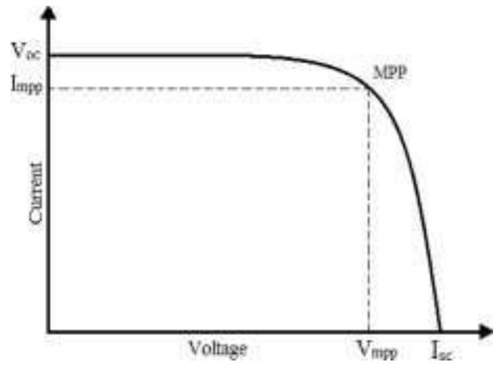


Fig.3PVarraycharacteristicswithMPPT

For a good solar cell, the series resistance (Rs), should be very small and the shunt (parallel) resistance (Rp), should be very large. For commercial solar cells (Rp) is much greater than the forward resistanceof a diode. The I-V curve is shown in Figure 4. The curve has three important parameters namely open circuit voltage (Voc), short circuit current (Isc) and maximum power point (MPP). In this model single diode equivalent circuit is considered. The I-V characteristic of the photovoltaic device depends on the internal characteristics of the device and on external influences such as irradiation level and the temperature characteristics of the PV cell are illustrated in figure 5. It depends on the open circuit voltage (Voc), the short circuit current (Isc) and the maximum power point (MPP).

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 12 | December - 2023 SJIF Rating: 8.176 ISSN: 2582-3930



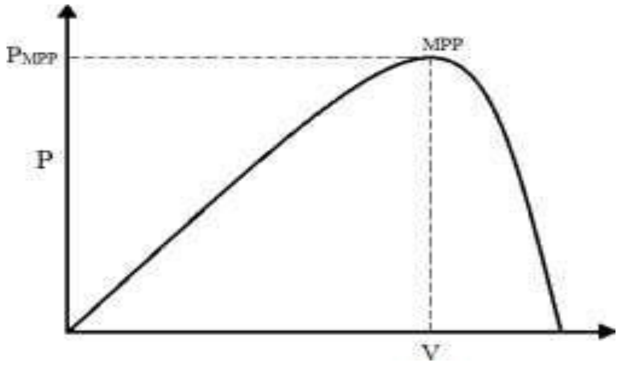


Figure 4.I-V characteristics of the PV cell **Figure 5.P-V characteristics of the PV cell**

4. DC/DC Boost Converter

A step-up converter is used in this research to connect a PV panel with a load in order to adjust the operating voltage and current of the PV panel at optimal values. The boost converter contains an MOSFET and a diode which are represented as a dual ideal switch U in order to simplify the circuit analysis. If U is a state of 0, the diode is ON and the MOSFET is OFF and vice versa if U is a state of 1. The boost converter contains also passive components an inductor L, an capacitor C and a resistance R. The operation principle of the boost converter can be demonstrated for each switching period under the continuous conduction mode(CCM) into two modes, the first mode is an ON mode in the duration the period $0 \leq t \leq ton$.

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller is used to move the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation and it also fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular because of its simplicity

The design ofa boost converter for a PV system is a complex task which involves many factors. In general, the input and output voltages of the boost converter are varied with the solar irradiances and load variations. The output voltage is also varied which follows the reference voltage generated from an MPPT controller. Thus the selection of boost converter components (the input inductor and the output capacitor) is a compromise between dynamic responses and the MPPT algorithm trigger time. The maximum value of the state variables should be calculated to estimate the value of the boost converter

5. Artificial neural networks (ANNs)

Artificial neural networks (ANNs) have been proven to be universal approximate or non-linear dynamic systems. They emulate nonlinear systems using a multilevel neural network Neural network has the potential to provide an improved method of deriving non linear models which is complementary to conventional techniques. This work deals with the application of an artificial neural networks based MPPT of PV systems. Back propagation neural network are utilized as pattern classifier. Back propagation neural network is an example of non- linear layered feed-forward networks. Back propagation constructs global approximations to non-linear input-output mapping. There are capable of generalizations in regions of the input space where little or no training data area available In the proposed work, we develop an MPPT method for stand-alone solar power generation systems via the neural network approach. Here, the output power of the PV array is adjusted by a DC/DC boost converter. Then the system is represented in the neural network model, where the partial derivative of the PV power with respect to the PV voltage is taken as the control output. With this neural network is been trained for the desired response

Dynamic neural network (DNN)

A Dynamic Neural Network (DNN) is a neural network that can alter its own topology to accept perpetual novelty. Perpetual novelty is data that is always changing. A DNN never finishes learning. ADNN always accepts the data shown to it. To achieve this, the DNN needs to not only change its knowledge, but the topology that stores it. A purely dynamic neural network never stops learning or changing its topology. The field of DNNs is in its infancy. Most DNN examples are only partially dynamic that is that they are dynamic during a particular phase of their use

The three variable inputs are given insulation (sun) temperature and duty ratio (for controlling the MOSFET switch) and these values are trained using Feed Forward Back Propagation network by giving different delay as feedback till achieving maximum voltage. There response for the following input of [90, 319, and 0.55] in dynamic characteristics is as follows

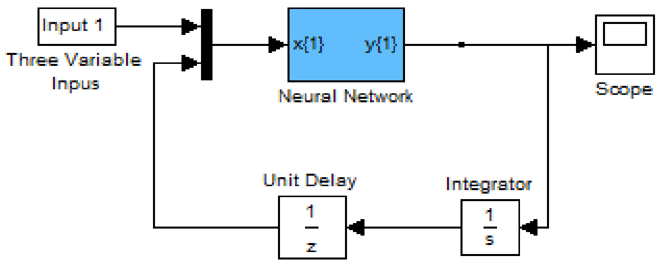


Fig.6 simulations for DNN

Static neural network (SNN)

A Static Neural Network (SNN) is a neural network in which desired output is obtained from desired input. A SNN is the one in which the output produced will be same for the particular range of inputs.

6. The Proposed MPPT model

6.1 Perturb and Observe (P&O) Algorithm

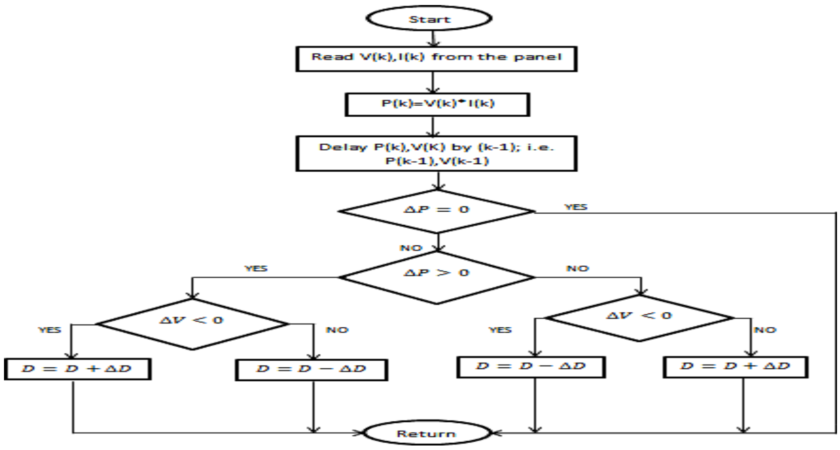


Figure 7 Perturb and Observe Algorithm

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller is used to move the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation and it also fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular because of its simplicity

A slight perturbation is introduced in this algorithm. The perturbation causes the power of the solar module to change continuously. If the power increases due to the perturbation then the perturbation is continued in the same direction. The power at the next instant decreases after the peak power is reached, and after that the perturbation reverses. The algorithm oscillates around the peak point when the steady state is reached.

6.2 Incremental conduction Algorithm

Incremental Conductance (IC) method overcomes the disadvantage of the perturb and observe methodin tracking the peak power under fast varying atmospheric condition. This method can determine whether the MPPT has reached the MPP and also stops perturbing the operating point. If this conditionis not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V.

This relationship is derived from the fact that dP dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm determines when the MPPT has reached the MPP, whereas P&O oscillates around the MPP. This is clearly an advantage over P&O. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe method [4]. The disadvantage of this algorithm is that it is more complex when compared to P&O. The algorithm can be easily understood by the following flow chart

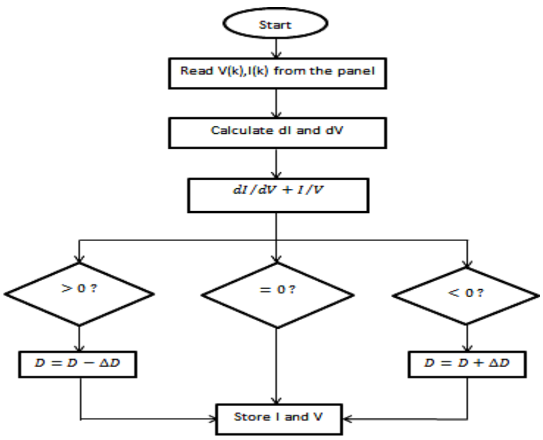


Figure 8 Incremental Conductance Algorithm

7. Conclusion

Interfacing an MPPT chopper between SPV and the load can maximize the power input to the load at all levels of insulation. This paper has presented the application of feed forward back propagation neural networks for maximum power point tracking of solar array. The back propagation neural network was modeled and simulated. The simulation results have shown that training of back propagation neural networks gives closer maximum power point. As the developed model takes care about the variations of all the parameters with respect to environmental conditions, it can be used to predetermine the SPV characteristics. The electronic load is useful for observing panel characteristics in the field conditions **.**In this paper a mathematical model of a photovoltaic panel has been developed using MATLAB Semulink This model is used for the maximum power point tracking algorithms. The P&O and Incremental conductance MPPT algorithms are discussed and their simulation results are presented. Itis proved that Incremental conductance method has better performance than P&O algorithm. These algorithms improve the dynamics and steady state performance of the photovoltaic system as well as it improves the efficiency of the dc-dc converter system. The outcome shows that INC strategy gives preferred outcomes over P&O technique and INC technique gives better execution under shifting environmental condition. Henceforth INC strategy can be utilized for MPPT of sunlight-based PV applications.

8. Reference

1 D. P. Hohm, M. E. Ropp, "Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed", 0-7803-5772-8/00,IEEE, 2000, 1699-1702.`

2 N. Pongratananukul and T. Kasparis, "Tool for Automated Simulation of Solar Arrays UsingGeneral- Purpose Simulators," in IEEE Conference Proceedings, (0-7803-8502-0/04), 2004, 10-14.

3 Trishan Esram, andPatrick L. Chapman, „Comparison of Photovoltaic Array Maximum PowerPoint TrackingTechniques,‟ IEEETransactions on Energy Conversion, 22 (2), 2007, 439-449
.

4. Hairul Nissah Zainudin, Saad Mekhilef, „Comparison Study of Maximum Power Point Tracker Techniques for PV Systems,‟ Proc. 14th International Middle East Power Systems Conference

(MEPCON"10), Cairo University, Egypt, 2010, 750-755.

5. Ahmed G. Abdullah. "Comparison between neural network and P&O method in optimizing MPPT control for photovoltaic cell". International Journal of Electrical and Computer Engineering (IJECE) Vol. 10, No. 5, October 2020

6 .D. Selvabharathi, Vishwas. "Design of standalone photovoltaic system using three port dc - dc converter". International Journal of Electrical Engineering and Technology (IJEET) Volume 11,

7. H.M.A. Maamary, H.A. Kazem, M.T. Chaichan, Renewable energy and GCC States energy challenges in the 21st century: A review, International Journal of Computationand Applied Sciences. 2 (2017) 11-18. https://doi.org/10.24842/1611/0018

8. M.A. Hannan, Z.A. Ghani, M.M. Hoque, M.S.H. Lipu, A fuzzy-rule-based PV inverter controller to enhance the quality of solar power supply: Experimental test andvalidation, Electronics 8 (2019) 1335. https://doi.org/10.3390/electronics8111335

9. IEA, "World Energy Outlook 2015," 2015. https://www.iea.org/reports/world-energy-outlook-2015

10. R. Belu, Artificial intelligence techniques for solar energy and photovoltaic applications, in: M.K. Pour, S. Clarke, M.E. Jennex, A.V. Anttiroiko, S. Kamel, I. Lee, J. Kisielnicki, A. Gupta, C.V. Slyke, J. Wang, V. Weerakkody (Eds.), Robotics: Concepts, methodologies, tools, and applications, IGI Global., 2014, pp. 1662-1720. https://doi.org/10.4018/978-1-4666-4607-0.ch081