An Efficient Algorithm for Energy Management in Smart Grid for Various Improvements

Deepa Kumari and Ashish Sharma

Abstract Set of algorithms are known as artificial intelligence (AI), and as per the current scenario, AI techniques, like expert systems (ESs), fuzzy logic (FL), and artificial neural networks (ANNs or NNWs), have changed the whole mode of operation by making power electronics and power engineering more advance in terms of their operation and control. With the introduction of this advancement, it has brought more efficient tools for blueprint, recreation, manage, evaluation, fault testing, and risk-tolerant control in recent smart grid (SG) and non-conventional power systems. The set of algorithms which we are talking about has achieved really quick development in the period of previous few years, and its impacts can be seen in the recent industrial applications. The implementation of different set of algorithms in smart power grids offers useful technical real-time support for the digital power system. Areas influenced by artificial intelligence in any smart power grid consist of energy management system, power generation, power supply, power system optimization, consumer behavior study, fault testing, etc. No enough data sample gathering, inadequate consistency, flawed infrastructure, need of special algorithm for power industry, etc., are the main problem which are still persisting for the existence of smart grid. Finding the solution and building the efficient algorithm for power industry can be the important tool to establish smart grid into the new era for electric network or power system. The paper will discuss the application of artificial intelligence for obtaining an efficient energy management system in any electrical grid.

Keywords Set of algorithms · Neural network · Customer behavior identification · Fuzzy logic (FL) · Neural network · Real-time data · Renewable energy systems (RESs) · Smart grid (SG) · Energy management system (EMS)

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1 Introduction

1.1 Smart Grid

Smart grid is one complete set of power system devices, computers, communication cyber technologies, and joint existence of recent information system and the conventional power grid [1]. As with the constant development in technology, we cannot stick to the old power generation system since they are superseded, unproductive, unpredictable and do not offer any efficient protection against the electric faults. Since smart grid is the one effective solution for all these conventional power systems, it can solve the problems of old power system like insufficient efficiency, poor load management, and poor fault analysis performance. The main area of focus by smart grid (SG) is as follows [2, 3]:

- Best possible resource deployment;
- Higher energy effectiveness;
- Higher system dependability;
- Higher system protection;
- Economically efficient electricity distribution

Keeping in view the current state of environmental health and climate change, smart grids can make hybrid power network system with different renewable energy systems (RESs) (solar, wind hydro, etc.) in addition to bulk conventional power plants (fossil, hydro, etc.) to overcome the problem [4]. It can also be installed with storage system (battery, pumped storage, flywheel, hydrogen, etc.) just because of unpredictable and fluctuating nature of renewable resources [5]. One of the best features offered by smart grid is its effective communication between supply and demand sides with the assistance of smart meters which helps to build the two-way communication between supplier and consumer and also decreases the use of bulk storage and offers economical tariff plans to the consumers [6, 7].

1.2 Algorithm

Algorithms mean "a method or group of rules to be obeyed in calculation or additional problems solving tasks". Hence, algorithms are set of instructions which step-by-step explain the execution of work in order to get the desired results [8, 9]. As algorithms are one step-wise explanation to the solution hence they are easy to understand also in any algorithm obstacle it is first broken down into steps are smaller pieces it becomes easier for the programmer to translate it into an actual problem but at the same time creation on an algorithm requires vast time so the development is quite time intense also splitting and iteration to show in any set of algorithms is difficult [10, 11].

1.3 Energy Management System (EMS)

This system of any electrical grid is that part which majorly deals with the operation and control tasks. One of those major areas of EMS is to sustain the stability between load side demand and power generation setting up generation economically, switching the substations of high-voltage transmission, keeping up good security for the operation of transmission system, and providing aiding solution to diagnosing problems (Fig. 1).

To diagnosing problems, monitoring the *N*-numbers of operations at consumer's end and collecting the information among the various remote terminal units are the most efficient area of energy management system [12, 13]. We can conclude that the energy management system is most importantly a monitoring and estimation system as far more data enter the energy management system than leaves. As it is already proven that the integration of unstable resources (like photovoltaic cells, wind generation, electric vehicles, and energy storage system) affects the stable functioning of power and distribution system [14–18], it is being a big concern due the power ratio between the supply and demand is not balanced [19]. An extreme/over deficiency in power production or consumption may end up causing serious problems as in blackouts, voltage drop/rise in severe situations. Hence, to make the generation and consumption system effectively balanced and to minimize the peak load during unpredicted stages, energy management system can be taken into count [20]. Energy management can be implemented in two different bases that is one at supplier's end such as electric grid, where the generators can be made operated alternately according to the fluctuation of lode demand [21] (Fig. 2).

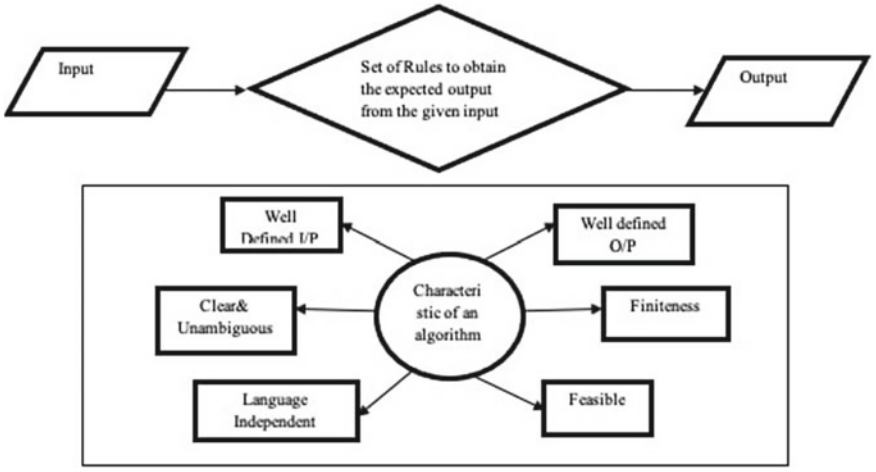

Fig. 1 Block representation of characteristics of algorithms

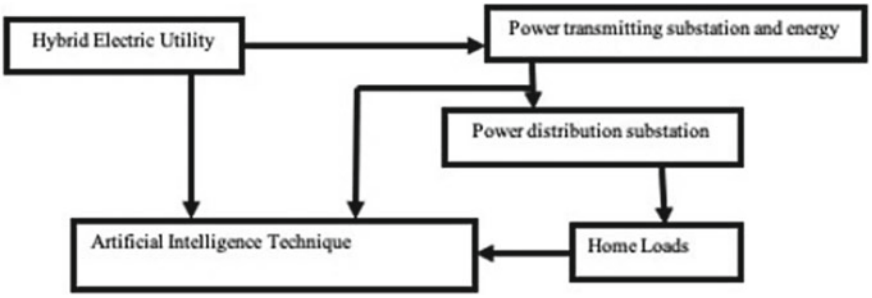

Fig. 2 Block diagram representation of dynamic regulation model with hybrid resources

2 Review of AI Techniques

There are basically four different areas to classify the AI techniques, i.e.,

- Expert systems (ESs);
- Fuzzy logic (FL);
- Artificial neural networks (ANNs or NNWs);
- Genetic algorithm (GA); or broadly evolutionary computation (EC).

As expert system, fuzzy logic, and neural network methods are normally used, these will be concisely reviewed [22, 23] under this segment. If there is any fastest evolving area in technology that we can say is an artificial intelligence and AI with its wide area of application is expected to serve its important features in the field of energy, transportation, health care, security etc. [24] (Fig. 3).

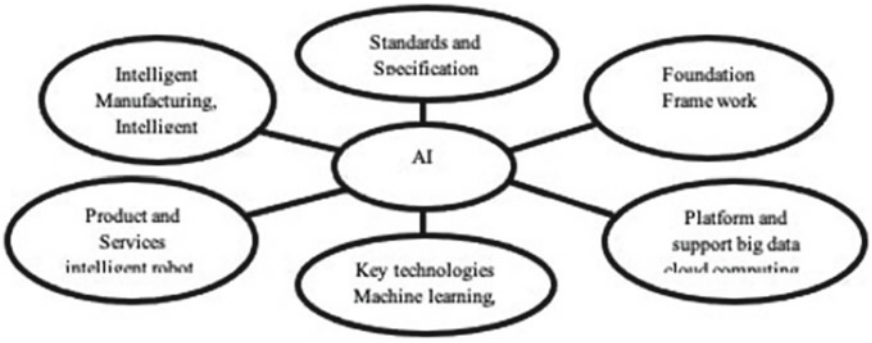

Fig. 3 Architecture of artificial intelligence

2.1 Expert System

Expert system is one of the intelligent computer programs which comprises Boolean logic function which is intended to insert the knowledge of human being in some specific areas as a result of which it can be implemented to crack the difficulty replacing human knowledge [25]. Although an expert system is an established technology, but so far it is not so applied in power system engineering [23]. We can trust the system in order to provide the high efficiency and performance to crack any difficult problem of a specific domain with high accuracy. User Interface, this is the feature with the help of which expert system interacts with the user, accepts the problem as an input in an editable format, and further processes it to the inference engine. Once the inference engine processes the data and gives response, it displays the response to the user [25]. So hence we can conclude that this that part of the system which allows the user to interconnect with expert system to find the resolution. Inference Engine (Rules of engine), this part of the system is acknowledged as the brain of the expert system as it is that unit which processes the main data. It implements rules of engine to the knowledge base to generate a result or to obtain new information. As the accuracy of expert system is very high, so it also helps to drive the most accurate solution of the query asked by the user. It is also that unit where the knowledge is extracted from the knowledge base [26]. Knowledge Base, it is that storage system of the system which stores the knowledge from the distinctive specialists of the particular area. It is then called as big packing of knowledge. The more the knowledge stored in knowledge base, more accurate the expert system will. It has similarity with database that contains information and rules of a particular domain. This can also be expressed as accumulation of objects and their attributes [27]. The use of expert system in energy management system: The encoding of information and implementing it to support operators require the integration of expert system inside the energy management system to such a level not currently conceived. In order to make applications' operation more expert system oriented, the run and sequencing logic of these application programs need to be changed [28]. In effect, any algorithm in the energy management system talks about the application of specific information regarding electric utility operation. For instance, almost every energy management system needs the existence of some logic that runs a condition estimator and security analysis on a habitual clock period with an supersede if switching events have occurred within a few seconds of the start additional [29]. The operative can call for an implementation of the condition estimator and safety analysis every time desired. With an expert system scheming, the state estimator and safety analysis events can be taken based on what type of switching accomplishment has taken place (Fig. 4).

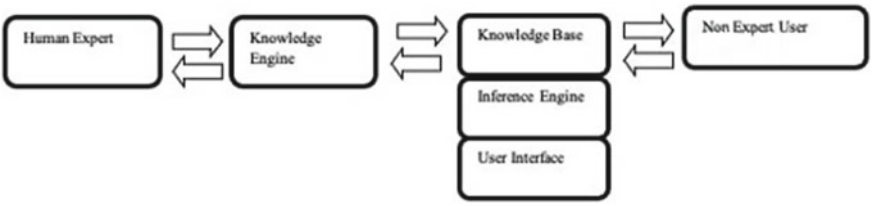

Fig. 4 Architecture of expert system

2.2 Fuzzy Logic

It is a way of thinking that pairs the human thinking. This procedure is alike to how human takes different decisions and it exhibits all intermediate possibilities between Yes and No [30]. It is a way of thinking that pairs the human thinking. This procedure is alike to how human takes different decisions and it exhibits all intermediate possibilities between Yes and No [31]. The old logic commands as per the computer understanding take exact input unit and generate a certain output as FALSE or TRUE which is exactly similar to human response as NO or YES. This algorithm was conceived after observing that human reacts in multiple ways under different conditions unlike computers where the output is limited between TRUE and FALSE, such as: can be as flexible as it can be fit for any size and proficiencies like microcontrollers, large networked or workstation-based organizations, and also it can be suitable for any hardware software or mixture of both [32]. Fuzzy logic has wide area of application; it can be suitable for commercial as well as practical purposes like:

- Fuzzy logic is one of the ways to command products of machine and consumer (Fig. 5).
- In accordance to human thinking if fuzzy logic is not able to provide exact thinking, it anyways can provide the satisfactory thinking.
- It benefits in commerce with the ambiguity in engineering rules. It comprehends search-required procedures and the necessary if–then statements presented by the

Fig. 5 Basic working of fuzzy

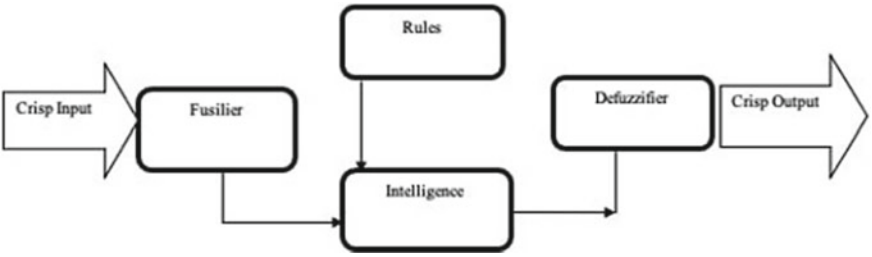

Fig. 6 Architecture of fuzzy logic

specialists to control any decision-making scheme. The current apprise in this algorithm offers multiple effective ways for the designing and modification of fuzzy logic controllers. Generally, this improvement minimizes the numeral of fuzzy rules [33].

Fuzzification is a conversion unit where the input or crisp numbers are converted into fuzzy sets. These crisp inputs can be processed by control system once measured by the sensors [33].

Inference Engine Amount of balance among fuzzy input and rules as per the input field is determined by this unit, and this unit will then choose the rules that need to be excited [33]. Defuzzification is the process of conversion of the given fuzzy sets into the crisp value. To do defuzzification, it has multiple types of practices present and the best-suited one is required to be selected with an expert system [15] (Fig. 6).

The Use of Fuzzy Logic in EMS

Fuzzy logic consists of input variables, and in fuzzy modeling, every input unit is first transformed to a fuzzy variable over a method termed as fuzzification. Fundamentally, this process converts any mathematical input into linguistic value. One specific variable in terms of using fuzzy logic for EMS is employed by the fuzzy logic energy management system (EMS) to make the electricity more economically affordable. It must be distinguished that the standardization progression utilized for charges—separating by the highest cost of the past few days—may allow the standardized value to be larger than one. Thus, the creation of dialogue in this fuzzy logic system is chosen to satisfy the desired range [25], which sufficiently covers the level for this variable.

2.3 Artificial Neural Network (ANN)

Set of algorithms forming Neural Network [34] is the very generic version of artificial intelligence; it is most likely to follow the genetic nervous system as associated to Expert system and Fuzzy Logic that is used to imitate the developmental nature of brain by means of the rule base. This algorithm (NNW) has the feature of nonlinear

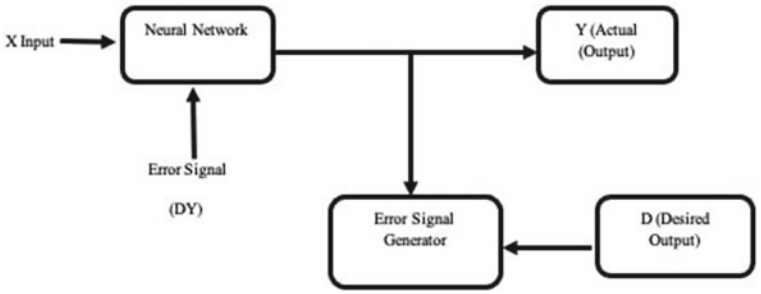

Fig. 7 Architecture of artificial neural network

i/p–o/p mapping or arrangement identification property which basically imitates the linking memory property of the human brain. This is the very significant part of artificial intelligence and is very well-organized in terms of solving pattern acknowledgment or image-processing mode troubles that are kind of tough to crack with conventional methods [35]. The combination or interconnectedness of manmade neurons can be termed as Neural Network, which further can serve its application in numerous engineering scientific and real-life problems [21, 22]. These NNW are of two main categories feedforward and feedback as per the flow of direction [16] (Fig. 7).

Feedforward Network

This is non-repeatable network having processing segments/node and these sections in a layer are joint along with the segments of preceding layer. The connections have dissimilar loads on them. Feedforward type does not have and response loop which means that the signal can stream in single direction, i.e., from input to output. Further, it may be described as follows [17].

Single-Layered Feedforward Network

Here, under this type, input layer is completely connected to output layer and this is that one of the concepts of feedforward ANN (Fig. 8).

Multilayer Feedforward Network

This is the idea of feedforward artificial neural network (ANN) having numerous subjective layers. As in this type there are more than one layer present between input and output layers, it is also called hidden layers [17, 18] (Fig. 9).

Feedback Network

As it is clear from its name, there will a feedback path which means that the direction of flow of signals can be in both the directions using loops. This makes the system dynamic and nonlinear. It changes uninterruptedly until it touches a state of steadiness [16, 17].

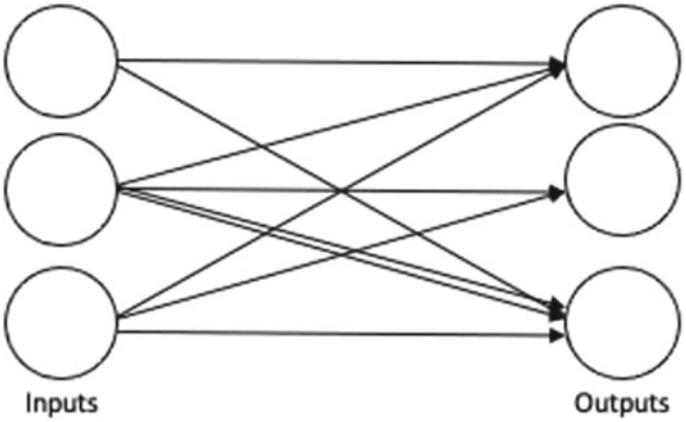

Fig. 8 Single-layer feedforward

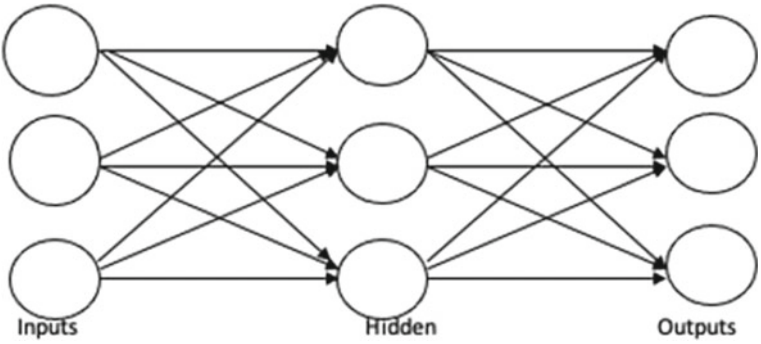

Fig. 9 Multilayer feedforward network

Recurrent Network

This is the greenest Neural Network design as all the nodes are linked to one another and every node functions as both input and output [22] (Fig. 10).

Jordan Network

It is a close path network where the outcome will get back to the input again as feedback as displayed in Fig. 11 [23, 24].

The Use of Artificial Neural Network in Energy Management System

Artificial neural network is one of the predicting algorithms which when utilized in any smart grid system can be used for predicting the consumption of energy. By implementing feedforward type of neural network, the prediction is according to as training function is TRAINLM, learning function LEARNGDM, performance function is MSE and LOGSIG as transfer function. In the whole process of artificial neural

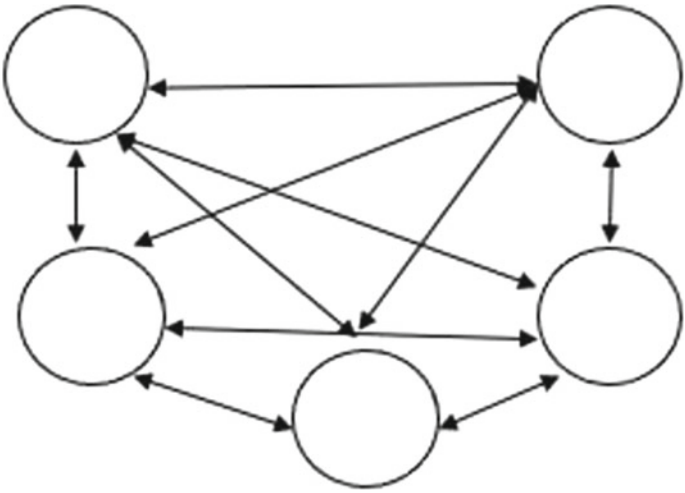

Fig. 10 Recurrent network

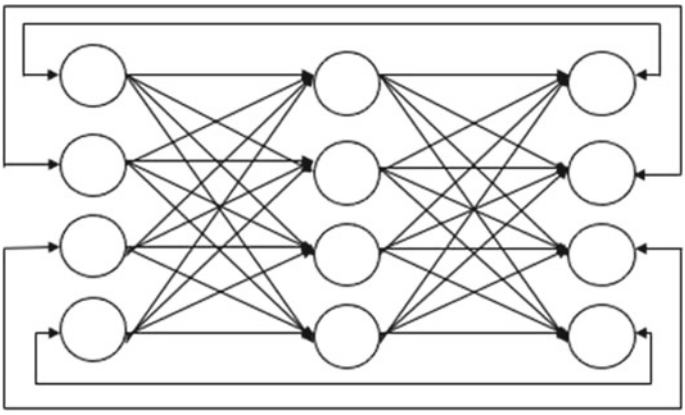

Fig. 11 Jordan network

network, consumption of power, number of experiments run, experiment hours, and cost of electricity act as input parameters and energy consumption is the output data.

3 Conclusion

As we know that the set of different algorithms will result into some artificial techniques and the artificial techniques are one most powerful tool for application in smart grid and non-conventional sources. This work gives as an idea about the

existing algorithms and their different types such as Expert system, Fuzzy logic, and artificial neural network; these are the significant branches of artificial intelligence, which is then trailed by the brief explanation of block architecture of AI and their different types? These discussions and explanations of different AIs are very interesting and can be implemented over a wide range of applications in smart grid. The algorithms' examples labeled in the paper can be stretched to cover various other functions in smart grid in integration with renewable resources. The implementation and consumption of any novel energy technologies impress more than a few challenges associated to this field (power management) of recent constructions that take the shape of prosumers. Allowing for substantial and time limitations of power management related to individuals, there is a requirement for smart energy management systems that accomplish an extra competent power depletion and decreased to achievable point of electricity bill autonomously of the atmosphere and weather circumstances.

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