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ANFIS: A Vision for Smart Electric Power Grid

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Abstract

It is important to implement safe smart grid environment to enhance people's lives and livelihoods. This paper introduces the general aspects of smart grid, which is combination of many latest technologies like fuzzy and artificial neural network for effective energy distribution and usage. From a conceptual point of view, the smart grid is the convergence of information and operational technologies applied to the electric grid, allowing sustainable option to customers and improve security. Smart grid technologies include advanced sensing system, two way high –speed communication monitoring and enterprise analysis software and related services to get location-specific and real time actionable data in order to provide enhanced services for both the system- operators. In this paper, architecture for fuzzy multi-agent based fault detection in smart grid is also proposed and provide vision for future power system. This would result in reduction of power losses and better utilization of generated power.

Keywords: Smart grid, neural network, fuzzy system, power system, load forecasting, consumer.

1. Introduction

A culture encroachment happens trough interplay of technology and everyday life. In the last decade, a new way of changes has been taken place in the power system; know under the name Smart Grid (SG), which has a significant influence on the electric generation, transmission and distribution system. The existing electric power Infrastructure designed and developed in the 20^{th} century is rapidly running up against its limitations: increasing transmission congestions, more frequent large blackouts and

limited flexibility to accommodate new ingredients such as wind and distributed energy resources [1].

A smart grid is a form of electricity network utilizing digital technology. The "Smart Grid" is envisioned to overlay the ordinary electric grid with an information and net metering system that include smart meters. It is a tool that allows electricity utilities to focus on evolving true business delivers by enabling cost containment, end-to-end power delivery control, and a more secure infrastructure. The grid is considered to have observability with nodes data integration and analysis to support advances in system operation and control.

The electricity infrastructure is moving from vertically integrated system to a restructured deregulated one. The electric power grid is considered to be the largest man – made infrastrutre.This colossal infrastructure has evolved over a period of about a century and functions as a complex adaptive system. However with ever increasing electricity demand the grid has been pushed to limits and its efficient and reliable operation has become a grave challenge.

2. Smart Grid and Its Smartness

2.1 What is Smart Grid

A smart grid is an advanced electricity transmission and distribution network (grid) that utilizes information, communication, and control technologies to improve economy, efficiency, reliability and security of the grid [2]. From vision of the U.S. Department of Energy(DOE),a smart grid should be "intelligent, efficient, accommodating, motivating, opportunistic, quality-focoused, resilient, and environment friendly"[1].The European smart grid ETP define the smart grid as " electricity network that can *intelligently* integrate the behavior and actions of all users connected to it-generators, consumers and those that do both-in order to efficiently delivers sustainable economics and secure electricity supplies"[3].

2.2 Characteristics of Smart Grid-

Smart grid is the convergence of information and operational technologies applied to the electric power grid allowing sustainable options to customer and improved security, reliability and efficiency to utilities. The challenges and needs are more important and urgent than ever before and will drive the present transmission grid to expand and enhance its function toward smarter features with fuzzy and artificial neural network.

The main consideration of smart grid is itsintelliegence, flexibility, digitalization, resilience, sustainability and customization. Smart grid to deal with the following challenges.

2.3 Security and Intelligence

A grid that mitigates and stands resilient to physical and cyber security attacks. Intelligent technologies and human expertise will be incorpated and embedded in the smart transmission grid. Smart grid will likely have a control system that analyses its

performance using autonomous reinforcement learning controller that have to manage the behavior of the grid forever changing environment due to some equipment failure [5].Self healing will be achieved to enhance the security of transmission grid via co-ordinate protection and control scheme by using real time information from embedded sensors and automated controls to detect and respond to system problems. A smart grid can automatically avoid power outages, power quality problems and service disorders.

2.4 Provide Power Quality-

The Smart power grid featured as optimized power flow, efficiency and environment friendly. Smart grid is connected to micro-turbines, renewable fuel cell and other distributed generation technologies at various levels. It may be local, national or international, integration of small –scale, localized or on-site power generation allows residential, commercial and industrial customers to self-generated and self excess power to the grid with minimum technical or regulatory barriers .This improve power quality and decarbonize with consideration to the environment and climate change.

2.5 Enable Metering Electricity Market and

Optimize Assets-

The smart grid will be capable of delivering electricity to customers securely and reliable in the case of any external on internal disturbance or hazards. The application of smart meter will provide customers the information regarding energy consumption that was not previously available with a traditional meter [7].

2.6 What Makes a Smart Grid 'Smart'-?

A common interpretation of the smart grid is that it is the combination of the electric power and communication infrastructures, charaterised by two way communications and two way energy flows. The smart grid is to be based on an 'Energy Web' an analog of internet and world wide web.. Intelligent use of information will be the core/brain of a smart grid. With the help of modern sensing and communication infrastructures, improving the intelligence in the operation, control and protection of power system is the only way to achieve the goals of the smart grid.

Also each computing resource, sensor, control element and so on will have a unique IP address, so that specific message can be exchanged among the elements. This capability will allow a heretofore unobtainable level of monitoring and control of the entire electrical grid and allow outside intruders or malicious insiders to damage the grid [8]

2.7 How can fuzzy Logic and ANN Smarten the Grids-

Fuzzy logic and neural network are nature-inspired methodologies for addressing complex problems, where traditional rigorous methods are ineffective or infeasible. They have been widely applied to many challenging real-world problems in signal processing, control, electric machine, communication, robotic etc. Its application in power system is not new. Among the ANN domain, different type of ANNs have been

developed, such as the multi layer perception(MLP) neural network, recurrent neural network(RNNs), echo-state networks(ESNs) and self organizing map[SOMs][10]. Intelligent closed loop methods using different ANNs and Fuzzy systems have also been studied. Out of the different intelligent control scheme the adaptive critic design (ACDs) proposed by Werbos, are among the most advanced one.

3. The Proposed Scheme of Fuzzy and ANN in Grid Management

As one important aspect of smart grids, development of sensors and communication brings the opportunity of increasing the visibility of traditional power grids.

When a new plant is being added to a power system or grid, the effects are quite complex-for example, when wind energy is added to a grid, it has no marginal cost associated with production, and therefore will always offer the cheapest power [11].

We proposed here, as a first step, a method to decide the best choice of a suitable generation source to supply a given electric load based on the relative cost of electricity from various available power source.

3.1 Interior Structure-

Fuzzy multi-agent based system is integrity of artificial intelligence with agent based control scheme[12]. Proposed interior structure of each agent is based on the principal of fuzzy controller theory. Therefore, it should basically be consisting of fuzzifier, interference engine and defuzzifier.fig.1illustriate diagram of overall proposed interior architecture for agents.

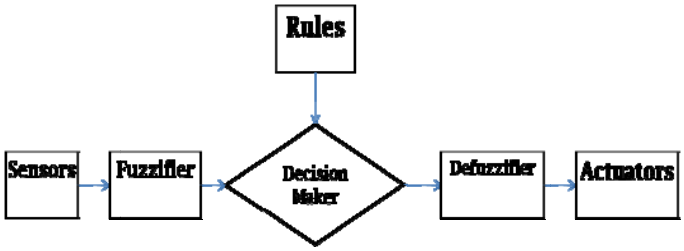

Fig. 1: Proposed interior structure of a single agent.

Fig. 1. depicts the architecture of a simple fuzzy controller.Fuzzy controller consists of a fuzzification interface, which receive the current values of the input variables and eventually transforms to linguistic terms or fuzzy sets. The knowledge base contains information about the domains of the variables, and fuzzy set associated with the linguistic terms. So the modeling becomes increasingly complex under this dynamic equation of different elements on the grids.

3.2 Optimization of Power Source-

The electric loads too have their own charaterctics and own relative properties e.g. a critical service like a hospital emergency will rate over-riding property over a cinema theater A flow diagram depicts the process of generator solution briefly in fig.2.

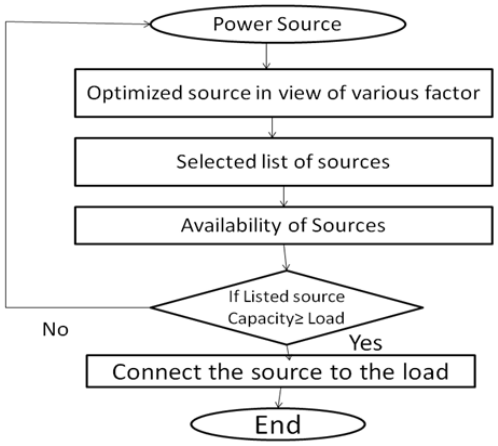

Fig. 2: Flow chart for the selection of Generation Source(s)

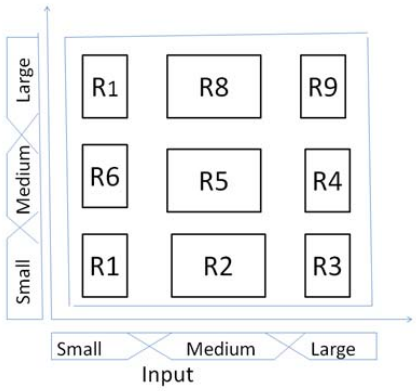

Fig. 3: Membership function for link selection

3.3 Selection of transmission path on grid-

Fuzzy logic help to create best path for connecting the selected generation source(s) to the load to be fed with power. There are main three main considerations [11] such as availability of the link, the cost due to transmission losses and the charges for usage to the owners of the transmission links

A fuzzy controller makes use of model of the expert who is in a position to specify the most important properties of the process A classifier rule triggers whenever its condition part matches the current input, in which case the proposed action is send to the process to be controlled. Referring to fig.3 ,a Mamdani or TSK rule may be formed as

If input-1 is medium and input-2 is large then rule R8 is fired

3.4 ANN Based Power System Protection-

The goal of power system is to quickly identify and isolate the faulted parts of a power system and allow as much of the network as possible to remain the operation it play a crucial role stopping disturbances from propagating across the network and preventing large blackout.

3.5 ANN Based Adaptive Relays-

Because of the operating point of a power system continuously changes, relay with fixed setting may mis-operate under certain operating conditions. Intelligent or adaptive relays were thus introduced to have as smarter protection scheme MLP neural network and SOMs,combined with feature extraction method such a Fourier transform and wavelet transform. Fig.4 show the schematic diagram of transmission line boundary protection relay proposed in [13], where two SOMs were used, one for differentiating integral and external faults(ANN#1) and the other one for classifying fault types (ANN#2).

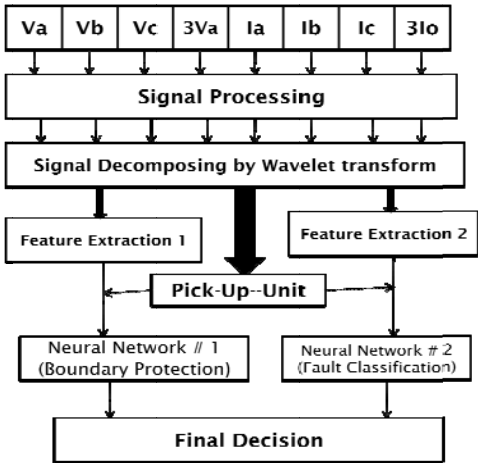

Fig. 5: Transmission line boundary protection scheme [13]

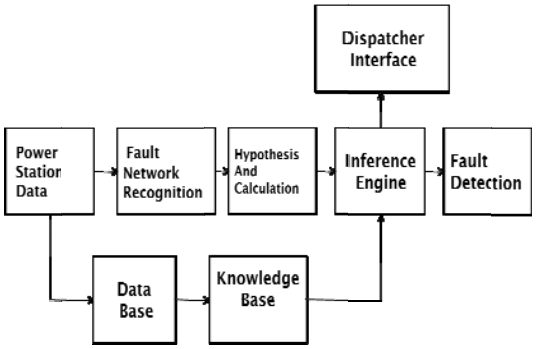

Fig. 6: Block diagram for fault detection using fuzzy logic

3.6 ANN based Auto –Reclosers

Besides intelligent relay for isolating faults,ANN have also been applied to design reclosing scheme for power line autoreclosers. An autoreclosers is a circuit breaker with automatic recloser after a protection trip. Advanced ANN based reclosing scheme were proposed with functions of identifying temporary faults and estimating reclosing time delay for complete arc extinction.

3.7 ANN and Fuzzy logic Based Fault Locating-

After a grid fault is isolated from the main system it is always desired to locate the exact faulted section of the system, based on available measurements and relay/circuit breaker signals.

An ANN-SVM based approach was proposed by Thukaram to locate faults in radial distribution systems based on only the voltage and circuit measurement at the substation [14]. Fault locations along the same feeder and different fault types were successfully classified on the feature planes by SVMs. A proposed scheme for fault detection using fuzzy logic is shown in fig.6.

4. Future Research Work

As the future work, we intend to explore the idea of automatic feature solution for our regression model in order to further improve the accuracy. In addition we plan to rigorously test our method with multiple smart grid load dataset from different countries/industries and fine tune method so as to ensure its general usability.

Future work is based on another scenario which tap change agent after rejecting request message, send a negotiation massage to another distributed generation to regulate voltage of target point by changing level of reactive power injection or consumption of them.

5. Conclusion

In the era of energy crisis smart grid is expected to be proven as reliable, efficient and sustainable option for modernizing the electric network. The development of such a smart power grid requires multidisciplinary research and engineering efforts, and more importantly, it needs intelligence and innovations in electric power engineering. A convolution rule –based expert system for power system requires several hundreds of rules, where as in fuzzy set based expert system many of the rules are replaced by the calculations of the membership function of the applied rules. This paper aims to contribute a sight for the reader to have a functional knowledge of the electric power grid and a better understanding of cyber security.

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