Knowledge-Based Decision Support for Smarter Restoration Plans in the Power Grid

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Abstract **- A large scale blackout is long term loss of electricity over a large geographical area. Large scale blackouts are rare events, but when they occur they have a huge impact on the society .To affect the life of millions of people. When a blackout occurs, it thus becomes hence absolutely essential to restore the power system as fast as possible to minimize its consequences. To succeed with this, it is necessary to be aware of restoration issues which might occur during the restoration process and how to avoid them. India, through being a developing country, full of natural resources and manpower, is still facing severe shortage of electricity due to overloading, mismanagement, transmission line losses, electricity theft issues, aged equipment, poor maintenance and questionable monitoring and control which put the power sector to a downfall. This paper thus aims to focus on the fast restoration of distribution systems under different load levels.**

Key words **- restoration plan, smart grid, ANN, distribution system**

I. INTRODUCTION

Modern power systems are highly reliable. They are operated to withstand the variability in system conditions that occurs in the course of normal operations, including the daily changes in load levels, generation dispatch, and equipment availability. Modern power systems also provide reliable service to load during unusual events, such as faults and the tripping of transmission lines or generating units. Extreme events can occur, however, that may lead to partial or total system blackouts. To recover from such catastrophic events, utilities thus have a responsibility to develop detailed plans and procedures for restoring the power system safely, efficiently, and as expeditiously as possible. When a fault takes place in a certain area of a power system, it is essential for the system operators to locate the fault, isolate the faulted block and restore the service to the out-of-service area. Service restoration is defined as finding suitable backup feeders and laterals to transfer the loads in out-of-service areas using operational criteria through a series of switching operations. [1]

Now a day's many transmission systems are not fully automated. For this, in most cases, the corrective actions that are required for the fault location, isolation and service restoration function are performed manually. This process may require more time than the self-healing feature of a smart grid, which can detect faults and reconfigure the network automatically. Therefore, one vital pillar of smart grids is self-healing, which can be described as the quality of a system that enables it, when subjected to a fault, to automatically and intelligently perform corrective actions to restore the system to the best possible state, thus enabling it to perform basic functions without violating any system constraints. The self-healing function will minimize the workload for the field human operators, provide almost immediate restoration for the customers, and improve reliability and robustness of networks. Smart grids therefore represent a promising solution for tackling these challenges through the development and enhancement of distribution automation, the distributed operation of functions, and the reduction or elimination of human intervention through the enhanced deployment of information, two-way communication technologies, and data management.
To signify the effectiveness of the proposed ANN methods, will be shown a fault on a demo distribution system. It is concluded from the test result that proper restoration plan can be reached by ANN method in a short time.

II. CURRENT POWER SYSTEM RESTORATION TECHNIQUES AND THEIR LIMITATION

Power engineers have been studying power system restoration (PSR) since 1980s with its goal to being to find fast and reliable ways to restore a power grid to its normal operational state after a black-out event. Based on the Co-operative Restoration Principle the techniques used as evaluation: [2-10]
1. Mathematical Programming Techniques for PSR
2. Knowledge Based Techniques for PSR
3. Petri Nets in PSR
4. Heuristic method
5. Metheuristic method
6. Learning method

The most important is that time taken to identify the plan and evaluation to the operation depends on characteristics of any grid. [2, 11, 12] These above techniques have some limitations. Knowledge based technique is proportional to the size of the system so it required several minutes to find the restoration plan. But in Mathematical Programming Techniques and Petri Nets use search algorithm to determine the restoration plan. The fastest search algorithm, the depth-first search, doesn't guarantee an optimum solution. Evaluation based on time taken by Mathematical Programming and Petri Nets techniques its performance depends upon the size of the state space. As the size of the state space increases, the search process takes a longer processing time that could increase even more if a load flow is needed after each state is obtained to check the state's feasibility. In Knowledge based technique in larger transmission systems where all restoration possibilities must be covered, the number of production rules increases significantly, which diminishes the technique's speed considerably. The heuristic rules (knowledge-based techniques or expert systems) based on the operator experience and beliefs, and has an advantange that operates on highly specific to the characteristics of the network and system. However they do not require complex mathematics nor advanced stochastic methods, therefore it simple. It has to be adapted with the evolution of network. For example the availability of more measures and more precise data means that information that has to be guessed heuristically can now be directly used. Moreover, the characteristics of the network and the priorities of the operators may evolve. [13] Metheuristic method [14-18] use random search (exploration) combined with heuristic (exploitation) and hence are classified as one of the stochastic optimization method. Here heuristic refers to the algorithm designers' judgment (and not based on a mathematical proof) for the solution candidate while for heuristic rules, it is based on operator working on the field. This category includes:-

- Ant colony (ACO),
- genetic (GA),
- immune (IA),
- simulated annealing (SA) algorithms
- tabusearch (TS).

The designer of the algorithm has to find good heuristics, set the initial parameters (that may be generated randomly) and fine-tune the parameters without guarantee so that they can adapt well to new situations. Learning methods: [13,19] gradually increase their knowledge as they receive more inputs. They can be used in a supervised or unsupervised manner to learn. It improves their performance over time. The learning algorithm used artificial neural network (ANN) methods with a fast response and real-time natures.

Thus when a fault takes place, the blackout area and the numbers of customers affected depend heavily on the effectiveness of service restoration algorithm. Generally, the system operators tend to restore the electricity power on the basis of their existing knowledge and heuristic rules. However, owing to a great number of feeder and lateral switches in a typical transmission system, it is not easy to restore an out-of-service area solely depending on the past experiences of human operators. The modern power system control centres need a paradigm shift in their architectural design to meet new challenges .Therefore, how to devise a fast and effective restoration plan with various load levels is of major concern in this paper.

III. PROPOSED SYSTEM ARCHITECTURE

The aim of our proposed work is to simulate the system design of smart grid. We simulate the development of mechanism of restoration plan through the use of Data mining technique .An Expert system which collect the real time data from various system parameters like current (3ϕ) ,voltage(3ϕ),frequency , angle ,historic data, area, region and etc . It is a neural network based expert system picking the system state and the fault type of node. Creating the training patterns and store the results in database. To developed a proper restoration plan for a given pattern.The proposed method of fault detection improved power system reliability through improved monitoring and control. The purpose is to reach a proper restoration plan underneath a fault event in the system.

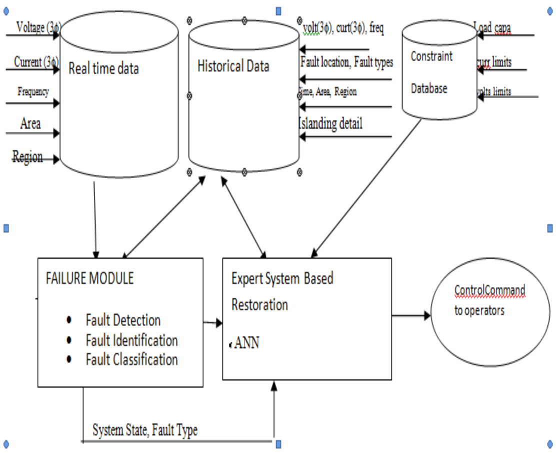

Fig 1: The Basic Block Diagram

The above figure (Fig 1) is the basic block diagram of the system. The configuration for the system consists of the various databases, failure module, expert system and monitoring the system based on which reports is generated.

IV. EXPERT SYSTEM BASED RESTORATION

The expert system based restoration module acquires its inputs from historical database, constraint database and the output of the failure module. A rue base consists of rules that formed to represent the logic used by an expert while solving a problem. Here the faulted nodes and the load of the supporting laterals, supporting feeder are the inputs to the ANN to find the restoration plan of the faulted section.

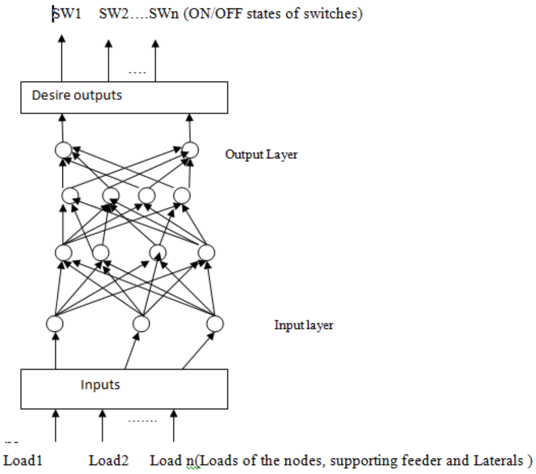

Fig 2: Design of ANN

The artificial neural network employed in this work is a multilayer feed forward neural network. The inputs are the loads of the nodes and the spare capacity of the supporting feeder and laterals. The nodes in the output layer provide us with the ON/OFF state of feeder switches. These states indicate the switches that must be operated in the restoration plan. In addition to the input layer and the output layer, we need one or more hidden layers in between. The nodes in the hidden layer take signals from the input layer and send their outputs to the nodes in the next layer when computations within the nodes have been completed.

Database – It consist of three databases i.e real time data, historical data and constraints data . The real time database is responsible for storing continuously coming real data i.e three phase voltage (Va, Vb, Vc),three phase current (Ia, Ib, Ic) and frequency (frq). The second database is responsible for storing historic and processed data from the for future purposes such as report generation and visualization. This database provides information to the failure module. It is also useful for suggesting necessary actions on the occurrence of failure based on the ranking of power grid nodes on the basis of severity of failure of the node. The constraint database stores operating-constraint data i.e. voltage limits, current limits, frequency limits, capacity load limits.

V. ALGORITHM

This algorithm uses as restoration plan for the system .It helpful to the operator to find the opening and closing of switches of the faulted section. [20]

Step 1: Create the training pattern.

The training data phase covers a various load levels of the node, capacity margins of the lateral and feeder are compute. The training pattern having the fault location, load of the nodes, lateral and feeder are compiled. As for the structure of the ANN, two hidden layers with 20 neurons at each layer are used.

STEP 2: The input data to the network can be defined as

$X=[x_1 , x_2 ,\ldots. x_n]^T$

these are the load of the nodes(in ampere) and the capacity margin of the feeders(in ampere)

As in ANN the input will be in the range 0.1 to 0.9 is recommended. So we use the formal to normalized inputs

$X=[x_1 , x_2 ,\ldots. x_n]^T$

where

$x_i = 0.8(x_i' - x'_{min})/(x'_{max} - x'_{min}) + 0.1$

where the x'_{max} and x'_{min} are the maximum value and minimum value of x'_i (i= 1,2…N)

STEP 3: The outputs of the training network are defined as follows.

$Y = [y_1 ,y_2 \ldots y_{n-1} ,y_n]^T$

STEP 4: In the testing phase, the outputs of the ANN shows the switches position so it must be in binary state (ON/OFF). Set the threshold ρ where ρ= 0.7 .If the output is greater than or equal to ρ than set output will be 1(close) otherwise 0(open).

VI. EXAMPLE

To demonstrate the performance of the proposed method, we uses distribution system where four nodes, two feeders and one lateral was consider. The node (N1) is directly connected to the main feeder (feeder1) through circuit breaker. Node (N1) has two child nodes namely N2 and N3 respectively. Node (N3) have also one child node namely N4. Node (N2) is also connected to a supporting lateral where as node (N4) is connected to another feeder namely feeder2.So there is total eight switches operating in this system. The fast restoration scheme was implemented using the MATLAB package.

In training phase a total 220 training patterns are covering with various load and capacity of the nodes and feeders. It uses 20 hidden layers with the learning rate η is 1.0 and momentum constant α 0.5 fixed.

Suppose node N1 exceed with its maximum capacity, so the node N1 is under the failure. As node(N1) is connected to nodes N2 and N3 respectively. We need to operate the switches if we want to restore the electricity service on the nodes from its supporting lateral or other feeder. So we need to open the switch number 2,3 and 5 ,close the switch number 4 and 6 respectively .The Feeder 1 and Feeder2 with capacity of 220,160 resp. and lateral with the capacity of 100.

Table1: Summary of the restoration plans for some faulty nodes

CONDITION	SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8	No.of switching operation
Normal	Close	Close	Close	Open	Close	**Open**	**Closed**	**Closed**	
N1 fault	Close	Open	open	close	open	close	close	close	5
N2 fault	Close	Close	open	Open	close	**Open**	**Closed**	**Closed**	**2**
N3 fault	Close	Close	close	open	open	open	Close	close	1
N4 fault	Close	Close	close	open	close	open	**Open**	**closed**	**1**
N1,N2 fault	Close	Open	open	**Open**	open	close	close	close	**3**
N1,N3fault	**Close**	**Open**	open	close	**Open**	**Open**	**Closed**	**Closed**	**2**

If there will be node failure based on the minimum number of switching operation the nodes to be restored can be in the order of either of N3,N4 and then N2, (N1,N3) and (N1,N2) at last N1.

Following figures show the result of the test data .Fig3 show the neural network training performance graph. Fig4 show the accuracy performance of individual nodes

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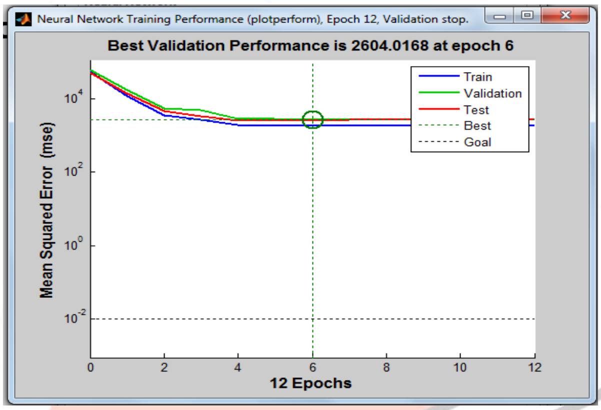

Fig3 Performance graph

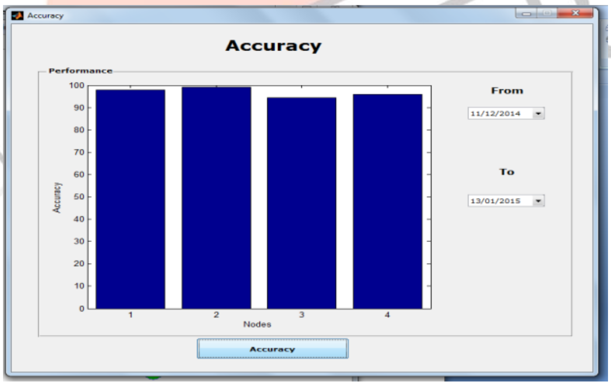

Fig 4 Accuracy performance of each node

VII. CONCLUSIONS

The proposed approach can cope with the restoration problem with various load variations is presented in this paper. It has been addressed for power system operator's reliable and fast restoration in case of the power system outages. The purpose is to reach a proper restoration plan following a fault event in the system. Employment of the ANN method an effort to reduce the execution time. Performance of the proposed restoration plans is verified through various case studies. Results showed a promising possibility of practical application.

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