A Neuro-Fuzzy Approach to Reactive Power Compensation for Improvement of Transmission Line Performance

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***Abstract*-- Reactive power control in transmission line has been an important problem for the last many years. The role of reactive power can be understood as it affects voltage stability, power factor and losses in a power system. To solve this problem many approaches have been used in the literature. Capacitors are utilized for the same. But the problem lies in finding the optimal location and size of the capacitors. This has been targeted by many researchers using evolutionary algorithms. This thesis proposes a novel idea of using Adaptive Neuro Fuzzy Inference System for finding the optimal placement of capacitors and size of the capacitors deployed. ANFIS based algorithm is designed utilizing neural network and fuzzy logic. The membership functions are formulated using an initial inference and then the weights of the common membership functions are found by using Neural Network. Gradient Learning is utilized for tuning. The results are found to be quite encouraging and convergence is achieved. The system is tested on a designed transmission T shape model.**

Keywords—Face recognition; Preprocessing; characteristics match; Image Processing etc.

I. INTRODUCTION

Power Compensation

During the past 20 years, the rise in current demand has conferred higher needs from the facility business. A lot of power plants, substations, and transmission lines got to be created. However, the foremost [4] ordinarily used devices in gift power system square measure the mechanically-controlled circuit breakers. The long change periods and distinct operation create them tough to handle the overtimes modified masses swimmingly and damp out the transient oscillations quickly. So as to compensate these drawbacks, giant operational margins and redundancies square measure maintained to safeguard the system from dynamic variation and live through faults. This not solely will increase the price and lowers the potency, however additionally will increase the quality of the system and augments the problem of operation and management. Severe black-outs happened recently in power grids worldwide and these have disclosed that typical transmission systems square measure unable to manage the management needs of the difficult interconnections and variable power flow. Therefore, investment is critical for the studies into the protection and stability of the facility grid, yet because the improved management schemes of the transmission. Completely different approaches like reactive power [2] compensation and section shifting are applied to extend the soundness and therefore the security of the facility systems.

Basic principal of power compensation in transmission

It shows the simplified model of an influence transmission. 2 power grids square measure [10] connected by a cable that is assumed lossless and painted by the electrical phenomenon XL. 11δ∠V and 22δ∠V represent the voltage phasors of the 2 power system buses with angle δ= δ1- δ2 between the 2.

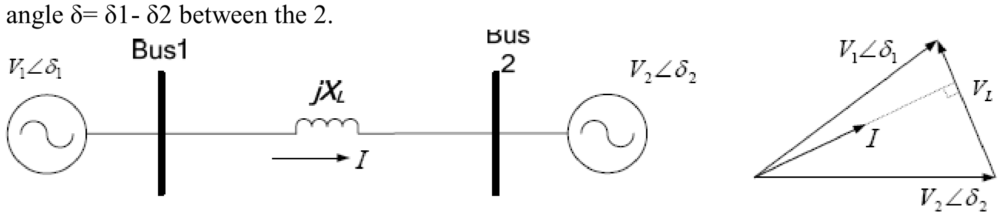


Figure: 1. Power transmission system: (a) simplified model; (b) phase diagram

The magnitude of this within the cable is given by:

$$I = \frac{V_L}{X_L} = \frac{|V_1\angle\delta_1 - V_2\angle\delta_2|}{X_L} \qquad (1)$$

The active and reactive parts of this flow at bus one square measure given by:

$$I_{d1} = \frac{V_2 \sin\delta}{X_L}, \qquad I_{q1} = \frac{V_1 - V_2 \cos\delta}{X_L} \qquad (2)$$

Reactive Power Compensation

Var compensation is delineated as management of the reactive power to prolong the performance of ac power systems. The most construct of the power unit compensation contains a good field of each client and system issues, connected with the facility quality problems, since power quality issues attenuated or solved with [11] adequate management of the reactive power. Within the drawback of reactive power compensation it are often viewed from 2 aspects: voltage support and cargo compensation. In load compensation objectives can be accustomed increase the worth of system power issue, to balance real power that is drawn from ac provide, to compensate voltage regulation, and to gift harmonic parts are often made by massive and unsteady nonlinear industrial masses.

II. LITERATURE REVIEW

Neelima, S. has described the distribution system is interface between bulk power system and consumers. Among these systems are radial distributions system is well known because of the low cost and design. In the distribution systems, the voltages at buses decreases moved away from the substation, also losses are large. The reason for decreasing in voltage and huge losses is insufficient amount of the reactive power that is provided by shunt capacitors [1].

Reddy, M. has projected two-stage methodology while using the fuzzy and Harmony search algorithm for placement of the capacitors on primary feeders of radial distribution systems with the objective to decrease power losses and to prolong the voltage profile. In first stage, fuzzy approach has been used to search optimal capacitor locations and second stage, the Harmony search algorithm has used to find search optimal sizes of capacitors [2].

Sarma, A. Kartikeya has plaanned an efficient approach for the capacitor placement in the radial distribution systems that define optimal locations of capacitor with an objective to improve voltage profile and reduction of the power loss. The solution has two parts: in part one loss sensitivity factors which are used to opt candidate locations for capacitor placement and two a algorithm that works Plant growth Simulation Algorithm is used to estimate optimal size of the capacitors at optimal buses determined in part one [3].

Sirjani, Reza has discussed the power systems capacitors which are used to transfer reactive power to decrease loss and to increase the voltage profile. The optimal placement of capacitors is important to ensure the system total capacitor costs and power losses are minimal. This capacitor placement problem has solved using the heuristic optimization methods that are diverse and subject of ongoing enhancements [4].

Abul'Wafa Ahmed R. had prescribed an effective and efficient approach for capacitor in radial distribution systems define optimal sizes and locations capacitors with objective reduction of power loss or improve voltage profile. A loss sensitivity method is used to opting candidate locations for capacitor placement. The size of optimal capacitor at compensated nodes which have been defined simultaneously to optimize loss save equation with respect to capacitor currents [5].

Singh, S. P., A had presented the particle swarm optimization method for searching optimal size and location of the capacitors which has reported in work. The method finds optimal places for shunt capacitors from daily load curve. Additionally, it defines suitable values of switched and fixed capacitors. The dynamic sensitivity analysis technique has used to opt candidate installation places of capacitors to decrease the search space of problem [6].

Rao, R. has displayed an efficient method for capacitor placement of radial distribution systems which describe optimal size and locations of the capacitor with objective to improve voltage profile and reduce power loss. The solution has two parts: in one part of the loss sensitivity factors which are used to choose candidate places for capacitor placement and new algorithm which works Plant growth Simulation Algorithm which is used for optimal size of the capacitors at fix buses defined in part one. The key advantage of technique is that it doesn't want any external control parameters [7].

Sarma, had invented a new technique that applies (ABC) artificial bee colony algorithm for the capacitor placement in the distribution systems with objective to improve voltage profile and reduces of power loss. The solution has two parts: in part one loss sensitivity factors are used to choose candidate locations for capacitor placement and in second part algorithm called Artificial Bee Colony Algorithm which is used to approximate the fixed size of capacitors at the optimal buses determined in part one [8].

Reddy, V. U. has discussed about the electricity which is not only become a necessity but also tool to determine economic growth and standing of a nation. The growth of exponential in demand over two decades and widening space between demands or supply is growing concern. So reducing the gap, in addition to include new creating units, automation technology employed to reduce the T&D losses and thus increases necessity of efficient and fast algorithms [9].

Kansal, Satish et al. has proposed an optimal placement of individual types of DGs which has been proposed. The optimal size and locations of DG's have defined to minimize power distribution loss. The power factor for DG supplying, both reactive and real power, has been attained in work. Individual types of DGs are supplying reactive and real power at individual bus has been considered in approach [10].

Franco, John F., et al defined a mixed-integer programming model to solve problem to allocate voltage regulators and switched capacitors in the radial distribution systems. The mixed integer usage linear model which guarantees to the convergence of optimality while using exist optimization software. In this model, steady-state operation of radial distribution system is modelled via linear expressions. [11].

Gallego et al. has been planned capacitor placement problem for the radial distribution networks that describes the capacitor sizes, types, control schemes and locations. Optimal capacitor placement is hard combinatorial problem which has been formulated as mixed integer nonlinear program. The NP complete problem the solution approach uses combinatorial search algorithm. The method has tested in range of the networks which available in superior results regarding both cost and quality of solutions [12].

III. PROBLEM FORMULATION

Application of shunt capacitors to the primary distribution feeders is a common practice in most of the countries. The advantages anticipated include boosting the load level of the feeder so that additional loads can be carried by the feeder for the same maximum voltage drop, releasing a certain kVA at the substation that can be used to feed additional loads along other feeders and reducing power and energy losses in the feeder. The objective of this paper is to solve the problem of reactive power compensation in transmission line to improve its performance. Even though considerable amount of research work was done in the area of optimal capacitor placement, there is still a need to develop more suitable and effective methods for the optimal capacitor placement. Although some of these methods to solve capacitor allocation problem are efficient, their efficacy relies entirely on the goodness of the data used.
The objective of capacitor placement in the distribution system is to minimize the cost of the system, subjected to certain operating constraints and load pattern. The three-phase system is considered as balanced and loads are assumed as time invariant. Mathematically, the objective function of the problem is given as:

$$min\ f = min(COST)$$

Where COST is the objective function which includes the cost of power loss and the capacitor placement. The voltage magnitude at each bus must be maintained within its limits as:

$$V_{min} \le |Vi| \le V_{max}$$

Where $|V_i|$ is the voltage magnitude of bus i, V_{min} and V_{max} are bus minimum and maximum voltage limits respectively. The problem of optimal allocation of the capacitor unit is formulated in the form of an optimisation problem. A cost function considering the voltage and the real power loss in the transmission line is formed.

OBJECTIVES

The objectives of this thesis can be described as follows:

- Designing of a Transmission Line model
- Application of TCR in the transmission line model
- Using Neuro-Fuzzy approach to control the TCR
- Comparative analysis on the basis of power, voltage, current and power factor.

IV. PROPOSED METHODOLOGY

The problem of TCR control of capacitors will be addressed in this thesis and it is proposed to utilize evolutionary algorithms for solving this problem. A T shaped transmission model bus system is used for testing our proposed algorithm. First of all, the bus system is designed as per the IEEE standards and the line losses and the voltage profile of all the buses are calculated using load flow studies

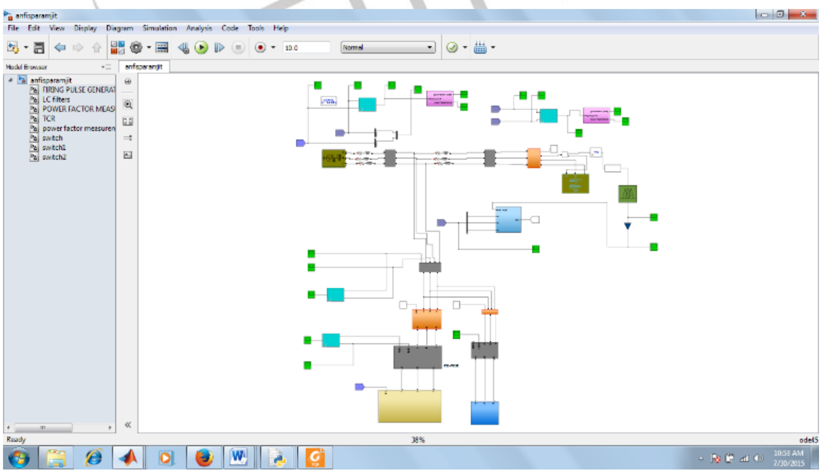


Figure: 2 ANFIS for compensation

Artificial Neural Network

An artificial neural network may be system support the operation of the biological neural networks, in individual words, is Associate in emulation of the biological neural system. Why would be crucial the implementation of artificial neural networks? Though computer recently is really advanced, there square measure bound tasks that program created for typical microchip can unable to perform; nonetheless a software package implementation of neural network may be created with the blessings and downsides.

Fuzzy Logic
Description of mathematical logic
In the recent years, amount and kind of applications of fuzzy logic have been multiplied considerably. The applications vary from the shopper product like camcorders, cameras, microwave ovens and laundry machines to process medical instrumentation, management, portfolio choice and decision-support systems.

Fuzzy approach
Fuzzy logic is conceptually straightforward to grasp. The mathematical idea behind the fuzzy reasoning square measure is easy. Fuzzy logic may be lot of intuitive approach while not far-reaching quality. Fuzzy logic is versatile. With given system, straightforward to layer on lot of practicality while not starting once more from scratch. The Concept of fuzzy logic is tolerant to the imprecise knowledge.

Problems with Fuzzy
Fuzzy logic is not a cure-all. Once you have to not use fuzzy logic? The safe statement is the initial one created during introduction: fuzzy logic may be a convenient to map Associate in input house to Associate in output house. If you discover it isn't convenient, attempt thing else. If less complicated resolution already exists, use it. Fuzzy logic is that the modifications of wisdom — use wisdom once you implement it and you'll in all probability build the correct call. Several controllers, as an example, do a fine job while not using fuzzy logic.

ANFIS
Adaptive control and neuron fuzzy control are two advanced methods for time-varying and non-linear processes. This course will begin with adaptive control of linear systems. Nonlinear systems and related control issues will be then briefly reviewed. Neural network and fuzzy model will be described as general structures for approximating non-linear functions and dynamic processes. Based on the comparison of the two methods, neuron fuzzy model will be proposed as a promising technology for the control and adaptive control of nonlinear processes.

ANFIS STRUCTURE
The adaptive network-based fuzzy inference systems (ANFIS) is used to solve problems related to parameter identification. This parameter identification is done through a hybrid learning rule combining the back-propagation gradient descent and a least-squares method.
ANFIS is basically a *graphical* network representation of Sugeno-type fuzzy systems endowed with the neural learning capabilities. The network is comprised of nodes with specific functions collected in layers. ANFIS is able to construct a network realization of IF / THEN rules.
Consider a Sugeno type of fuzzy system having the rule base
1. If y is $B1$ and x is $A1$, then $f_1 = c_{11}x+c_{12}y+c_{10}$
2. If y is $B2$ and x is $A2$, then $f_2 = c_{21}x+c_{22}y+c_{20}$

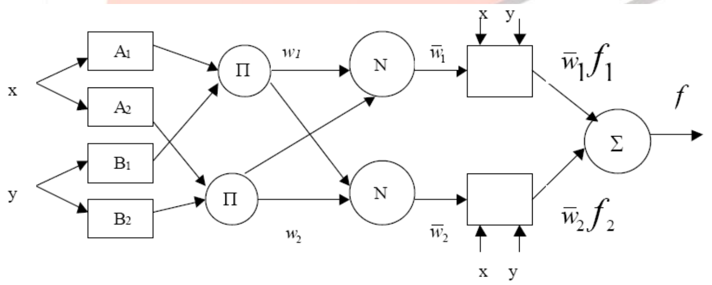


Figure 3: Structure of the ANFIS network.

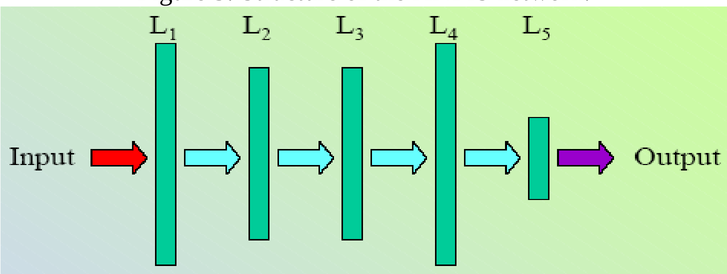
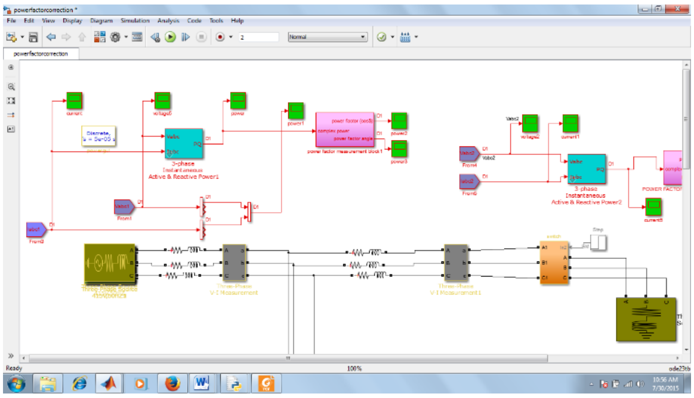
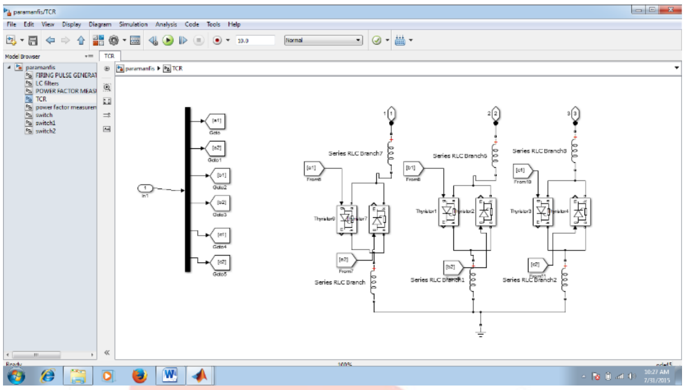


Figure 4. ANFIS Architecture

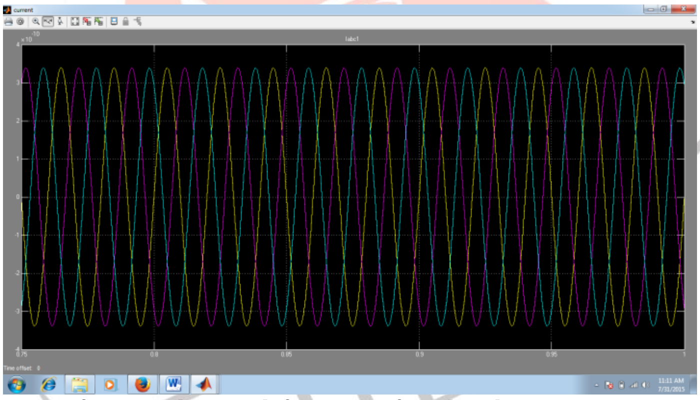
V. SIMULATION RESULTS AND DISCUSSION

This chapter discusses the various simulation results obtained by implementing the proposed algorithm explained in previous chapter for our problem statement. All the simulations have been done MATLAB R 2013b with a 6GB RAM computer with core i5 processor.

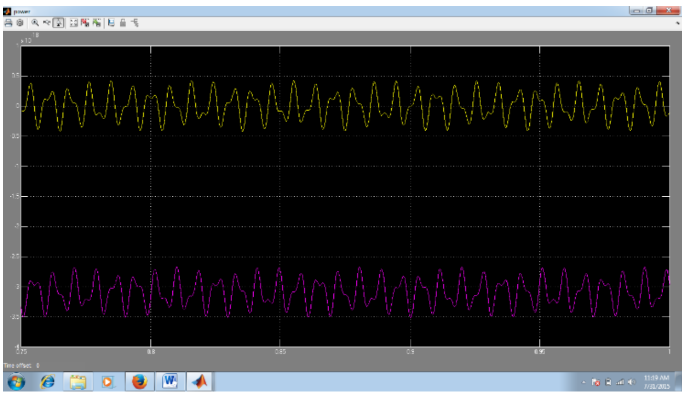




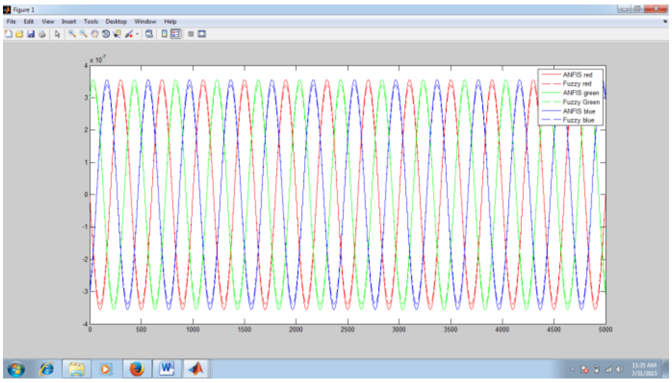
The THD of the current is minimised through ANFIS which controls the firing angle of the TCR as shown below.



The THD in current in case of neuro fuzzy and normal fuzzy are found to be 7.29 * 10^-5 and 6.3 * 10^-3 respectively. As observed, there is a significant decrease in the current THD in our proposed approach.
The voltage waveform in our proposed approach and normal fuzzy are shown below.
When compared in terms of power the following represents the real and reactive power in our proposed approach and normal fuzzy.



The THD in voltage our proposed approach and normal fuzzy are found to be 0.03779 and 0.139.
Also shown below is a comparative graph of both the methodologies in a single graph.



The power factor obtained in our proposed approach is found to be 0.8328 and in normal fuzzy is found to be 0.79. As observed, there is an improved power factor in our proposed approach.

VI. Conclusion and Future Scope

A novel idea of Adaptive Neur0-Fuzzy Inference System has been developed in this thesis to solve the reactive power control problem of the power system. Reactive power is an important parameter in power system which affects many factors such as stability, voltage level, losses etc. To find the optimal location of the capacitor to control the reactive power is a challenging task. To solve this problem a novel approach has been discussed in this thesis. The system has been tested T type transmission model. The results are found to be quite satisfactory the losses are minimised which was the target of the proposed algorithm.

In future, other algorithms can be tried on the same bus systems. Also the proposed algorithm can be tested on other bus systems. Also hybrid algorithms can be developed to solve the problem. Also STATCOM and SSSC etc can be used to enhance the performance.

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