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Reactive Power Compensation on 132 KV Substation Using Soft Computing Techniques (Fuzzy Logic)

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Abstract

In this paper we proposes an automated solution based on fuzzy controller to switch capacitor banks where in which all the decisions are based on the actual data points such as load, voltage levels and reactance in the systems. Additionally the proposed solutions helps maintain voltage levels, control voltage fluctuations, improve power factor and minimize human intervention resulting in the improved and efficient system. We also provide the result analysis with the discussion on the improvement in our strategy in comparison to the previous.

Keywords

Fuzzy Controller, Power Factor, Reactance, Capacitance

1. Introduction

After studying several research works in the field of Reactive Power Compensation, the demand for controllable reactive power source has gone up mainly for efficient and reliable operation of ac electric power system [1]. VAR compensators should be controlled to provide rapid and continuous reactive power supports during static and dynamic power system operating conditions [2]. Flexible AC Transmission systems (FACTS) controllers are emerging as an effective alternative to increases or enhance power transfer capability and stability of the network by redistributing the line flow and regulating the bus voltages. Static VAR compensator (SVC) and Thyristor controlled series compensator (TCSC) are some of the commonly used FACTS controllers [3]. Power System Stability is the ability of the system to regain its original operating conditions after a disturbance to the system [4]. Power system transient stability analysis is considered with large disturbances like sudden change in load, generation or transmission system configuration due to fault or switching [5].

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It is very important to stable the voltage supply, so that the performance is increases and because of the stability the loss is reduces. The main elements for generation and absorption of reactive power are transmission line, transformers and alternators. The transmission line distributed parameters throughout the line, on light loads or at no loads become predominant and consequently the line supplies charging VAR.

The Static VAR Compensator (SVC) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids[6] [7]. The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system [6]. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive)[6].

The remaining of this paper is organized as follows. In Section 2 we discuss about fuzzy control method. Related work in section 3.In section 4 we discuss about proposed work. In section 5 we discuss the result analysis. The conclusions are given in Section 6. Finally references are given.

2. Fuzzy Control Method

A fuzzy control system is a control system based on fuzzy logic which is a mathematical system for the analysis of analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0.

Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value.

The most common shape of membership functions is triangular, although trapezoidal and bell curves are also used, but the shape is generally less important than the number of curves and their placement. From three to seven curves are generally appropriate to cover the required range of an input value, or the "universe of discourse" in fuzzy jargon.

It is a collection of logic rules in the form of IF-THEN statements, where the IF part is called the "antecedent" and the THEN part is called the "consequent". Typical fuzzy control systems have dozens of rules.

Consider a rule for an even number generation:
IF ("value is divisible by 2") THEN ("number is even"). Because of the logical applicability the uses of fuzzy controller in a very wide area including power system.

The below Figure1 shows a microcontroller chip with a simple feedback controller:

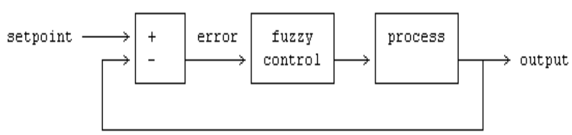

Figure 1: microcontroller chip with a simple feedback controller

A fuzzy set is defined for the input error variable "e", and the derived change in error, "delta", as well as the "output", as follows:
LP: large positive
SP: small positive
ZE: zero
SN: small negative
LN: large negative

3. Related Work

In 2009, N.Karpagam et al. [4] discusses about Static VAR Compensator (SVC) which is a shunt type FACTS device which is used in power system primarily for the purpose of voltage and reactive power control. Authors developed a fuzzy logic based supplementary controller for Static VAR Compensator (SVC) which is used for damping the rotor angle oscillations and to improve the transient stability of the power system. Generator speed and the electrical power are chosen as input signals for the Fuzzy Logic Controller (FLC). The effectiveness and feasibility of the proposed control is demonstrated with Single Machine Infinite Bus (SMIB) system and multi machine system (WSCC System) which shows improvement over the use of a fixed parameter controller.

In 2010, Karuppanan P et al. [8]describes the proportional integral (PI), proportional integral derivative (PID) and fuzzy logic controller (FLC) based three phase shunt active power line conditioners (APLC) for the power-quality improvement such as reactive power and harmonic current compensation generated due to nonlinear loads. PI, PID controller requires precise linear mathematical model and FLC needs linguistic description of the system. According to the authors the controller is capable of controlling dc capacitor voltage and generating reference source currents. Hysteresis current controller is used for current control in PWM voltage source inverter. Extensive simulation studies under transient and steady states are conducted, the simulation result analysis reveal that the APLC performs perfectly in conjunction with PI, PID and FLC.

In 2012, S.Kavitha et al. [9] aims at designing and implementing a fuzzy controller for Multiple Input Single Output temperature process. Temperature control of water in the tank is achieved by varying current to the heating rod and inlet flow rate by a fuzzy controller. According to the author the system consists of a tank, reservoir, variable speed pump, temperature sensor placed inside a heating tank containing the heating rod, voltage controlled current source and computer. Water is pumped into the tank from reservoir and RTD measures the current temperature. The signal from the temperature sensor is sent to the DAQ interfaced to the computer. LabVIEW software is used to acquire the input signal and send the output signal that is determined by the control algorithm. Fuzzy logic controller is designed in LabVIEW. Based on the set point temperature, the controller sets the appropriate current to the heating rod. If the required temperature is less than that sensed by the temperature sensor, the flow rate of water into the tank is controlled by a variable speed pump. While conventional controllers are analytically described by a set of equations, the FLC is described by a knowledge-based algorithm. Thus this system is highly efficient in both heating and reducing the temperature of the tank. A fuzzy logic controller gives faster response, is more reliable and recovers quickly from system upsets. It also works well to uncertainties in the process variables and it does not require mathematical modelling.

In 2012, R.krishna sampath et al. [3] discuss about STATCOM (Synchronous Static Compensator) based on voltage source converter (VSC) is used for voltage regulation in transmission and distribution system. The STATCOM can rapidly supply dynamic VARs required during system faults for voltage support. Strict requirements of STATCOM losses and total system loss penalty preclude the use of PWM (Pulse-Width Modulation) for VSC based STATCOM applications. They propose and develop an "emergency PWM" strategy to prevent over-currents (and trips) in the VSC during and after single line to ground system faults, LLLG faults and to ensure that the STATCOM supplies required reactive power. System performance during a nonlinear load connected without any fault is also considered. The Simulation results are shown for a 48-pulse VSC based ± 100 MVAR STATCOM connected to a 2-bus power strategy to prevent VSC over-currents and to supply required reactive power under line to ground system faults.

In 2012, Ashish Choubey et al. [10] discusses to enhance power supply reliability for the user terminals in the case of the distribution system to avoid interference by the fault again, rapidly complete the automatic identification, positioning, automatic fault isolation, network reconfiguration until the resumption of supply of non-fault section, a microprocessor-based relay protection device has developed. As the fault component theory is widely used in microcomputer protection, and fault component exists in the network of fault component, it is necessary to build up the fault component network when short circuit fault emerging and to draw the current and voltage component phasor diagram at fault point. In order to understand microcomputer protection based on the symmetrical component principle, they obtained the sequence current and sequence voltage according to the concept of symmetrical component.

In 2012,D.Raaga Leela et al. [11]an EP and PSO based optimization algorithms have been proposed for solving optimal power flow problems with multiple objective functions. These algorithms take into consideration all the equality and inequality constraints. The improvement in system performance is based on reduction in cost of power generation and fuzzy based network security. The proposed algorithms have been compared with the other methods reported in the author's literature.

In 2012, Arti Pateriya et al. [12] discusses about the growth of complex electrical power networks introduces lack of controllability of active and reactive power flow in energies networks Power flow control in an existing long transmission line, plays an important role in power system area. Their paper employs the shunt connected compensation STATCOM based FACTS devices for the control of voltage and the power flow in long distance transmission line. The proposed device is used in different locations of transmission line and also deals with determination of the optimal location of shunt flexible A.C. transmission line (FACTS) devices for a long transmission line for voltage and power transfer improvement. The results also show the line loading and system initial operating conditions.

In 2013, M.Apsar Basha [6] discusses that the Flexible AC Transmission System (FACTS) technology is a promising technology to achieve complete deregulation of Power System i.e. Generation, Transmission and Distribution as the complete individual units. According to the author FACTS is based on power electronic devices, used to enhance the existing transmission capabilities in order to make the transmission system flexible and independent in operation. The loading capability of transmission system can also be enhanced nearer to its thermal limit without affecting the stability. Complete closed-loop smooth control of reactive power can be achieved using shunt connected FACTS devices. They present the design and simulation of the Fuzzy logic control to vary firing angle of SVC in order to achieve better, smooth and adaptive control of reactive power in transmission systems.

In 2013, Shyamal Sen et al. [13] presents a piecewise linear approximation method for solving separable quadratic programming problems by using linear fuzzy goal programming (FGP) methodology. In the proposed approach, the objectives are first described fuzzily by introducing imprecise aspiration level to each of them. The fuzzy goals are then characterized by their associated membership functions for representation of goal achievement in terms of membership values of fuzzy goals. In the model formulation of the problem, the defined membership functions are first transformed into membership goals by assigning the highest membership value (unity) and introducing under-and over-deviational variables to each of them. Then, the membership goals in quadratic form are transformed into linear goals by using piecewise linear approximation method. In the solution process, minimization of under- deviational variables in the goal achievement function under the minsum FGP solution approach is considered. To illustrate the proposed approach a numerical example is solved. The model solution is also compared with the solution achieved by using Taylor series approximation method.

In 2013, Bijay Baran Pal et al. [14] presents how fuzzy goal programming (FGP) method can be efficiently used modelling and solving power generation and dispatch (PGD) problems in power system operation and planning horizon. According to the authors objectives of a problem involved with optimal power flow computation are considered fuzzy in nature in an uncertain decision environment. In the solution process, minsum FGP methodology is addressed to minimize the deviations from the aspired goal levels and thereby to reach a satisfactory decision on the basis of needs and desires of the decision maker (DM) in the decision making context.

4. Proposed Work

There are few solutions, that allow handle the problem of reactive power compensation. One of them is reactive power compensator basing on power capacitors. The technique has been deployed on almost all of the substations across India. Still it is not effective and precise in order to achieve desired results due to manual switching of the capacitor banks resulting in no significant improvement along with more cost of installing, maintaining and switching capacitor banks.

Heuristic decision making: the decision of switching in and out of capacitor banks to control the voltage levels is based on the past experience and not based on actual data points. The voltage levels when the capacitor banks are switched in/out may not be as thought as predicted by the heuristic information. Manual and error-prone switching: human handling of the system is always error-prone which applies here as well Decision based on unknown data-points: since the switching decision is heuristic based actual data-points are not known. The existing system is shown in figure2.

In this paper we proposes an automated solution based on fuzzy controller to switch capacitor banks where in which all the decisions are based on the actual data points such as load, voltage levels and reactance in the systems. Additionally the proposed solutions helps maintain voltage levels, control voltage fluctuations, improve power factor and minimize human intervention resulting in the improved and efficient system. The proposed system is shown in figure 3. As shown in figure 3 the input value is inputted through a three phase controller when the condition is on. There is several range of voltage which is control by the fuzzy controller and produces the output.

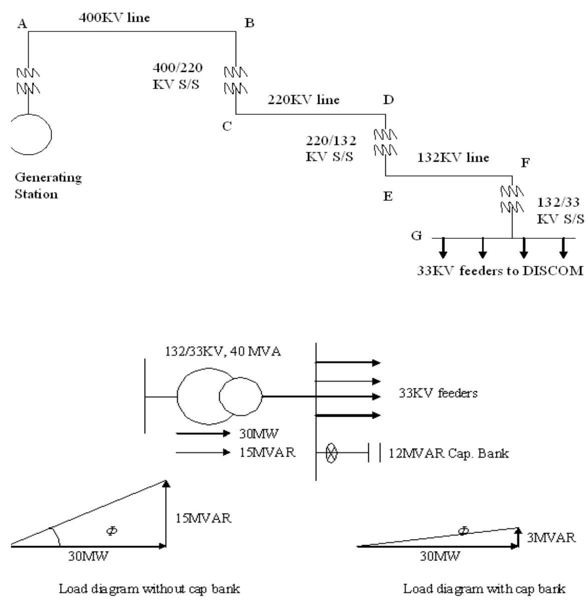

Figure 2: Existing System

The workings of Fuzzy Controller are shown below:

1) Define membership function for input and output.
2) Create membership function using values.
3) Add rule to fuzzy controller.
4) Determine your procedure for defuzzifying the result.

For defining membership for input and output and membership function using values, we follow the following steps:
Step 1: First we have to fuzzify the data or create membership values for the data and put them into fuzzy sets.
Step 2: Put simply, we have to divide each set of data into ranges.
Step 3: The Y value will always be on a range of 0 to 1 (theoretically 0 to 100%).
Step 4: The X will be an arbitrary range that we determine.
Then we generate a rule table, so that the rules are added to the fuzzy controller. The rule table is generated in the following manner:

Step 1: The rule table must now be created to determine which output ranges are used.
Step 2: The table is an intersection of the two inputs.
The results are combined to give a specific value, the actual brake pressure, a procedure known as "defuzzification".This combination of fuzzy operations and rule-based "inference" describes a "fuzzy expert system". In our case the parameters are capacitance, reactance and power factor. Our main advantage of the system is the system is automated and out performs on the variation based on capacitance, reactance and power factor.

Working of Switch:
Switch has five pins

- **Primary side**: to power and ground.
- **Secondary side**: normally connected(ground), common, normally open (transmission line)
- **Common** is connected to capacitor
- **Primary Side** is connected controller
- **Secondary Side** to switch:to connect the capacitor bank to transmission line, we should give '0' to primary side, so the controller pin is connected to inverter , so that '1' is converted '0' to activate the secondary side means capacitor bank is connected to transmission line
- if '1' is given as input('0' from controller) , common is connected to normally connected(ground), means switch is grounded.
- if '0' is given as input('1' from controller) , common is connected to normally open (transmission line), means switch is connected to transmission line.

Then got 60 values for 3 inputs based on the step size and corresponding 60 values for 3 outputs based on formulas of capacitance, reactance and power factor.
So the fuzzy controller: 1. membership function 2. Set rules 3. do fuzzy 4. Defuzzy

Finding the min and max for each input and output

```
a=newfis('fuzzy_controller1');
Voltage_max_limit=max(voltage_output);
Load_current_max_limit=max(Load_current);
power_output_max_limit=max((power_output));
Reactance_req_max_limit=max(Reactance_req);
capacitance_req_max_limit=max((capacitance_req));
Voltage_min_limit=min(voltage_output);
Load_current_min_limit=min(Load_current);
power_output_min_limit=min(power_output);
power_factor_min=min(p);
power_factor_max=max(p);
Reactance_req_min_limit=min(Reactance_req);
capacitance_req_min_limit=min(capacitance_req);
```

For each input and output and corresponding min and max we get 24 values, from membership function, input Membership Functions and voltage Membership Function.

```
[x1 x2 x3 x4 x5 x6 x7 x8 x9 x10 x11 x12 x13 x14 x15 x16 x17 x18 x19 x20 x21 x22 x23 x24]=Fn_Limits_For_8_MFs_Trimf(Voltage_min_limit,Voltage_max_limit);
```

Load Current Membership Function

```
[i1 i2 i3 i4 i5 i6 i7 i8 i9 i10 i11 i12 i13 i14 i15 i16 i17 i18 i19 i20 i21 i22 i23 i24]=Fn_Limits_For_8_MFs_Trimf(Load_current_min_limit,Load_current_max_limit);
```

Power output Membership Function

```
[p1 p2 p3 p4 p5 p6 p7 p8 p9 p10 p11 p12 p13 p14 p15 p16 p17 p18 p19 p20 p21 p22 p23 p24]=Fn_Limits_For_8_MFs_Trimf(power_output_min_limit,power_output_max_limit);
```

Output Membership Functions
Reactance_Required Membership Function

```
[y1 y2 y3 y4 y5 y6 y7 y8 y9 y10 y11 y12 y13 y14 y15 y16 y17 y18 y19 y20 y21 y22 y23 y24]=Fn_Limits_For_8_MFs_Trimf(Reactance_req_min_limit,Reactance_req_max_limit);
```

Capacitance Required Membership Function

```
[c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c16 c17 c18 c19 c20 c21 c22 c23 c24]=Fn_Limits_For_8_MFs_Trimf(capacitance_req_min_limit, capacitance_req_max_limit);
```

Power Factor

```
[pf1 pf2 pf3 pf4 pf5 pf6 pf7 pf8 pf9 pf10 pf11 pf12 pf13 pf14 pf15 pf16 pf17 pf18 pf19 pf20 pf21 pf22 pf23
pf24]=Fn_Limits_For_8_MFs_Trimf(power_factor_min,power_factor_max);
```

Rules:

```
1 8 1 1 1 8 1 1
2 7 2 2 2 7 1 1
```

3 6 3 3 3 6 1 1
4 5 4 4 4 5 1 1
5 4 5 5 5 4 1 1
6 3 6 6 6 3 1 1
7 2 7 7 7 2 1 1
8 1 8 8 8 1 1 1
Then we add the above rules.

5. Result Analysis

For result analysis we are considering the following values:
Frequency=50;
voltage_step_size=10;
current_step_size=25;
Power_step_size=12;

Load_current=Load_current_per_phase:current_step_size:(Load_current_per_phase+(No_of_iteration*current_step_size)-current_step_size);
b=numel(Load_current)
power_output=(power_output_per_phase):-(Power_step_size):(power_output_per_phase-(No_of_iteration*Power_step_size)+Power_step_size);

Then we calculate the power factor
for i=1:No_of_iteration
power_factor(i)=power_output(i)/(sqrt(3)*voltage_output(i)*Load_current(i));

The capacitance and reactance required
for i=1:No_of_iteration
Initial_power_factor_angle(i)=acosd(p(i));
Final_power_factor_angle(i)=acosd(power_factor_required);

The comparison based on capacitance, reactance and power factor as shown in figure 4, figure 5 and figure 6. So our result provides the following consideration after comparison:

- Precise and Accurate
- Stability
- Efficiency
- Capacity
- Losses
- Power factor improvement.

6. Conclusion

In this paper we proposed an automated Reactive Power Compensation on 132 KV Substation Using Soft Computing Techniques (Fuzzy Logic) and fuzzy controller. We discuss the proposed work with the advantages and achieved results. We also discuss the result analysis and show the better performance and effectiveness of our approach.

References

[1] S.Y. Lee, C.J. Wu, W.N. Chang: A Compact Control Algorithm for Reactive Power Compensation and Load Balancing With Static VAR Compensator, Electric Power Systems Research, Vol. 58, No. 2, pp. 63-70, 2001.

[2] P.K. Shadhu Khan, J.K. Chatterjee: Operational Capability of Inductively Loaded Current Controlled Solid-State Lead–Lag VAR Compensator, International Journal of Electrical Power & Energy Systems, Vol. 25, No. 4,pp. 275-292, 2003.

[3] R.krishna sampath, C.kumar, “Dynamic Performance of STATCOM under Various Faults in Power System”, International Journal of Advanced Computer Research (IJACR), Volume-2, Number-4, Issue-6, December-2012.

[4] N.Karpagam , D.Devaraj, “Fuzzy Logic Control of Static Var Compensator for Power System Damping”, International Journal of Electrical and Electronics Engineering,2009.

[5] P.Kundur, Power System Stability and Control, Mc Graw Hill, Newyok, 1994.

[6] M.Apsar Basha,” Reactive Power Compensation In Transmission Line By Using Online Static Var Comensator With Fuzzy Control Method”, International Journal of Engineering Research and Applications (IJERA)Vol. 3, Issue 1, January-February 2013, pp.082-085.

[7] A.M. Kulkarni, “Design of power system stabilizer for single-machine system using robust periodic output feedback controller”, IEE Proceedings Part – C, Vol. 150, No. 2, pp. 211 – 216, March 2003.

[8] Karuppanan P and Kamala Kanta Mahapatra , “PI, PID and Fuzzy logic controller for Reactive Power and Harmonic Compensation”, ACEEE Int. J. on Electrical and Power Engineering, Vol. 01, No. 03, Dec 2010.

[9] S.Kavitha, B.Chinthamani, S.Joshibha Ponmalar, “Fuzzy Based Control Using Lab view For Temperature Process”, International Journal of Advanced Computer Research (IJACR), Volume-2, Number-4, Issue-6, December-2012.

[10] Ashish Choubey, Latika Pande,” Analysis of fault using microcomputer protection by symmetrical component method”, International Journal of Advanced Computer Research (IJACR), Volume-2, Number-3, Issue-5, September-2012.

[11] D.Raaga Leela, Sairam Mannem and Ch.Padmanabha Raju,” Static security analysis of power system networks using soft computing techniques”, International Journal of Advanced

Computer Research (IJACR) Volume-2, Number-4, Issue-6, December-2012.

[12] Arti Pateriya,Nitin Saxena ,Manoj Tiwari," Transfer Capability Enhancement of Transmission Line using Static Synchronous Compensator (STATCOM)", International Journal of Advanced Computer Research (IJACR),Volume-2, Number-4, Issue-7, December-2012.

[13] Shyamal Sen, Bijay Baran Pal," A Piecewise Linear Approximation Method to Solve Fuzzy Separable Quadratic Programming Problem", International Journal of Advanced Computer Research (IJACR), Volume-3, Number-1, Issue-8, March-2013.

[14] Bijay Baran Pal, Mousumi Kumar," A linear Fuzzy Goal Programming Method for Solving Optimal Power Generation and Dispatch Problem", International Journal of Advanced Computer Research (IJACR),Volume-3, Number-1, Issue-8, March-2013.

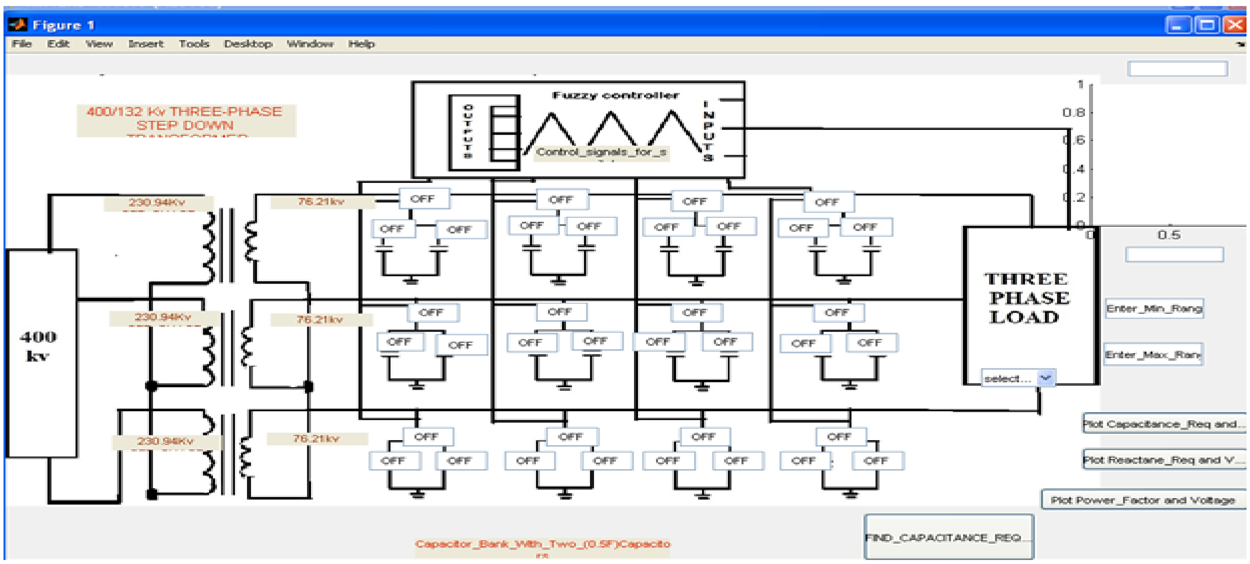

Figure 3: Proposed System

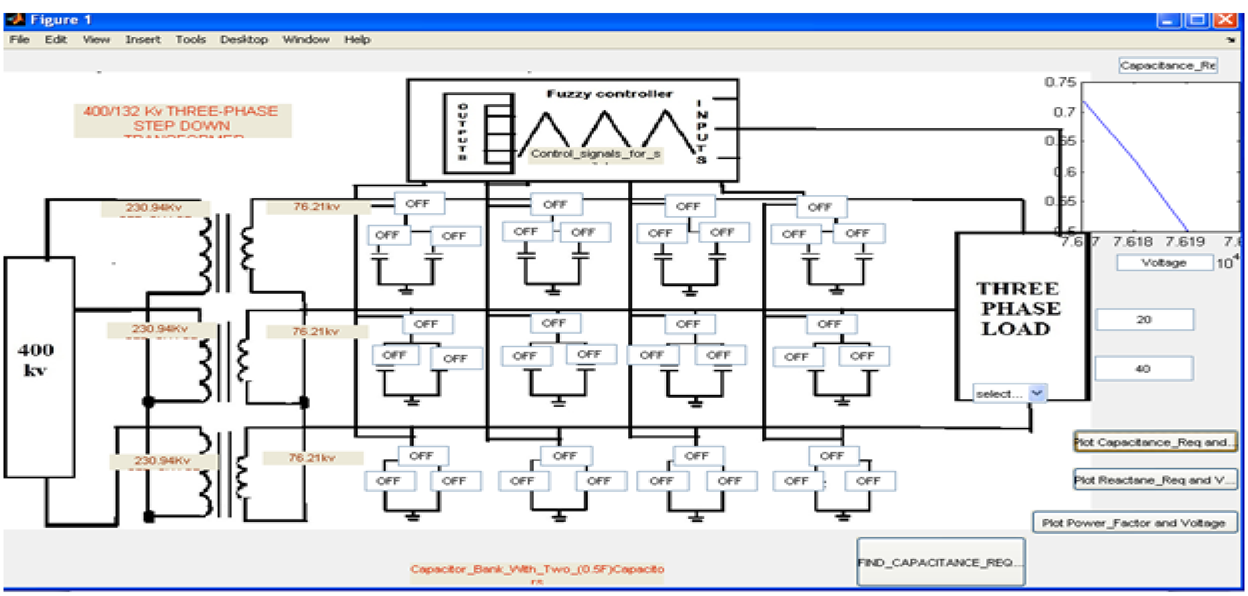

Figure 4: Capacitance Based Result

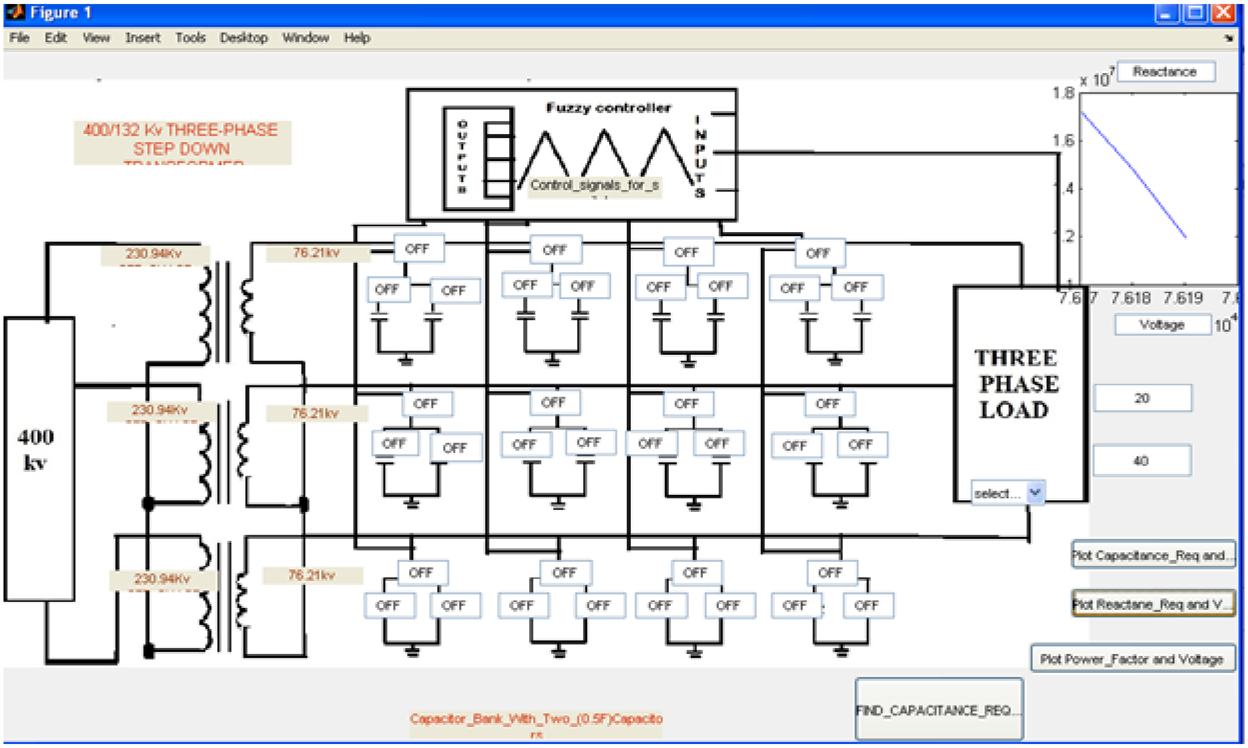

Figure 5: Reactance Based Result

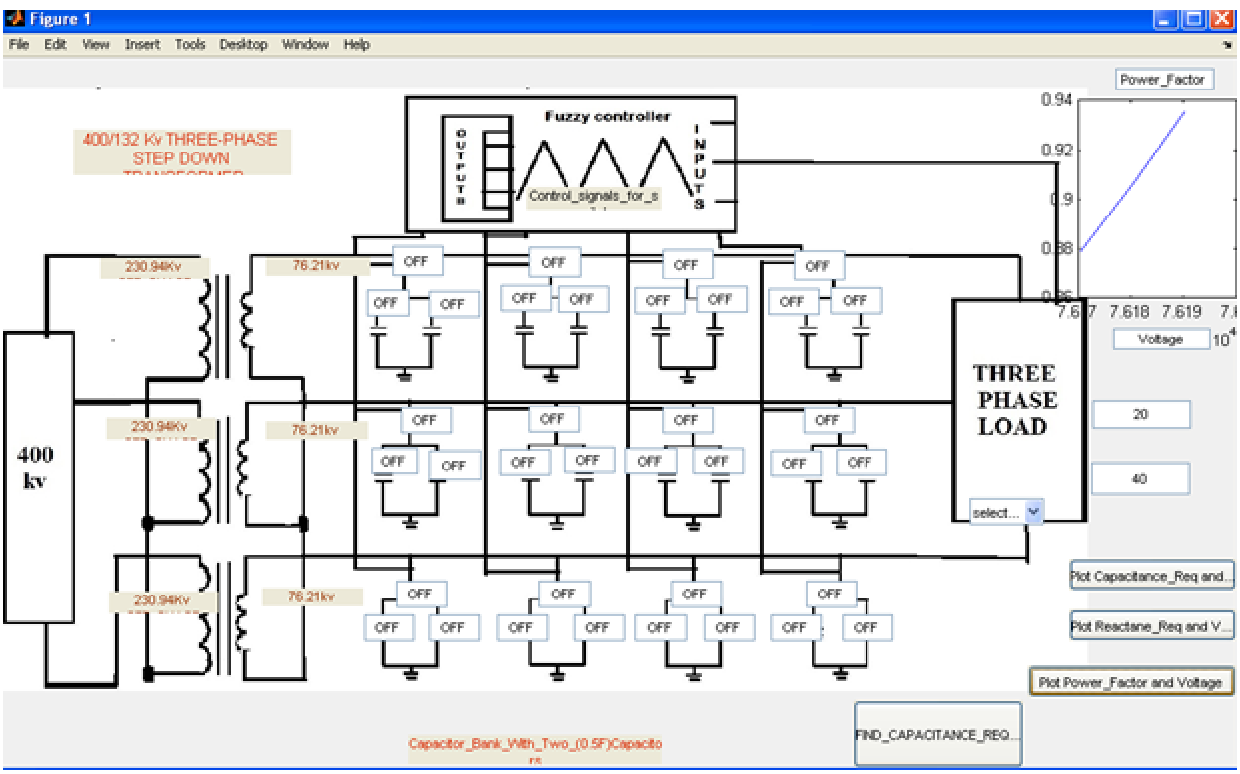

Figure 6: Power Factor