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Line Loss Minimization in Distant Substations and Multiple Cycle Distribution Systems Using UPFC

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ABSTRACT

This paper introduces the loss minimum least condition in isolated substations and same substation various circle dispersion systems by utilizing the unified power flow controller (UPFC). For every situation, the numerical model is exhibited and the line loss minimum conditions are gotten taking into account the line parameters of the circulation feeders. Since different loop appropriation system is bolstered from same substation, the line loss minimization can be accomplished by compensating the summation of the line reactance voltage drop. In a confined substation circle dispersion system, the line loss minimization can be accomplished by compensating the summation of the line reactance voltage drop notwithstanding the voltage contrast of the substations.

I. INTRODUCTION

Nursery gas discharges are viewed as one of the most essential issues that influence our surroundings and causes environmental change. Electrical Energy supplies are considered as one of the primary benefactors in global warming since they discharge carbon dioxide (CO2), Hence, worries over a worldwide temperature alteration issues have prompted change the operation and configuration measures for conveyance systems. The most important of these is the energy saving. Line loss minimization in distribution systems is the most effective arrangement with a specific end goal to accomplish energy saving.

Moreover, line loss minimization improves the voltage profile along the circulation feeders.

Furthermore, The nonstop expanding of the power request. Subsequently, as the interest power increments on these systems, power quality issues, for example, high power loss frequently turn into a huge issue. In a perfect world, the force misfortune in electrical systems ought not to be more than 6%. In any case, in

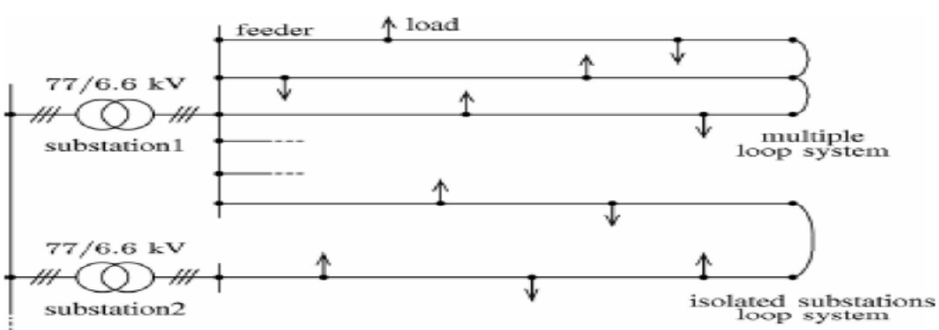

Figure 1: Configuration of the distribution system

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created nations, the force misfortune is more than 10%, while in creating nations; it is more than 20%. Accordingly, conveyance system engineers have proposed a circle system to accomplish the benefits of line loss reduction what's more, to improve the load voltage profile along the feeders. In spite of the fact that, the circle conveyance system requires complex assurance plans it is additionally more solid administration that is offered for basic loads, for example, healing centers. Therefore, much of late research works have considered reconfiguring the outspread appropriation system to circle one keeping in mind the end goal to accomplish these goals.

The confined substations loop system results from reconfiguring two outspread feeders nourished from various substations to perform one circle, while the different circle system results from reconfiguring more than two outspread feeders nourished from same substation to perform no less than two adjacent loops. In the segregated substations circle system, a loop current may results from the voltage distinction between substation voltages notwithstanding the asymmetrical line parameters of the feeders. In a various loop system, a circle current may results from the asymmetrical line parameters of the feeders, just, since its feeders are fed from the same substation.

The creators have proposed the line misfortune least conditions in circle circulation systems, and tentatively accomplished these conditions by utilizing the brought together power stream controller (UPFC). The creators proposed load voltage direction to be equivalent in the extent to the source voltage under line misfortune least condition. In any case, the proposed procedure can't promise the other load voltages to be inside the admissible voltage range. The creators proposed a new strategy for controlling all load voltages to be inside the admissible voltage range under line misfortune least condition by controlling both the heap voltage extent and stage point to take after reference values. The reference load stage point was ascertained from the line misfortune least condition, while the reference voltage greatness was computed in view of the voltage greatness of every heap tuned in system. Line loss minimization can be accomplished if the circle current is disposed of from the loop system. This condition can be accomplished if, at any rate, the line parameters of all loop lines have the same proportion between the resistance and inductance. This can be acknowledged in the same substation loop appropriation system since it has stand out substation for the entire loop, though in a confined substations loop system this condition can't be acknowledged because of the voltage contrast between them, which may come about because of little contrast in the size or phase angle. The distinction between the substation voltages results in an over the top loop current that will stream on top of it lines regardless of the fact that the loop line parameter proportions are same.

II. MODEL OF THE ISOLATED SUBSTATIONS LOOP DISTRIBUTION SYSTEM WITH THE UPFC

The UPFC is utilized as a part of a circle dissemination system as a series compensator to control the power current on top of it lines all together to accomplish line loss least condition. Fig. 2 demonstrates a basic

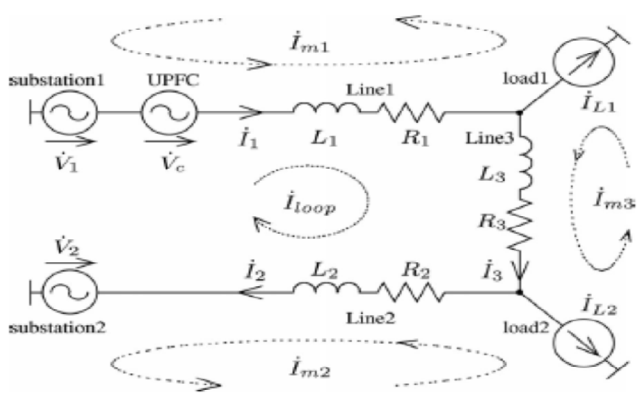


Figure 2: Model of the isolated substations loop distribution system

Model of the separated substations circle circulation system with the UPFC identical circuit. Since the UPFC shunt converter is utilized to direct the dc-link voltage, its current is little and can be dismissed. Consequently, the UPFC is improved as series voltage source that speaks to the series converter voltage. The circle system is spoken to by three conveyance lines (Line 1, Line 2, and Line 3). Every line has its resistance (Ri) and inductance (Li), where i is the line number (i = 1, 2, 3). The line impedance is spoken to by Zi = Ri + jωLi. Since the circle system is segregated substations, it is supplied from various substations spoke to by two voltage sources (V1 and V2). The system encourages two loads spoke to by consistent current sources (IL1 and IL2). The line current of every line insider loop system currents in the same course. The UPFC series infused voltage is spoken to by the voltage source (Vc).

(A) Before Installing the UPFC

The line streams Iÿi (i = 1, 2, 3), that stream in every line of the loop system, before introducing the UPFC, can be figured utilizing Superposition hypothesis as takes after:

$$\dot{I_1} = \frac{(\dot{Z}_2 + \dot{Z}_3)\dot{I_{L1}} + \dot{Z}_2 I_{L2} + (\dot{V_1} - \dot{V}_2)}{\dot{Z_{LOOP}}}$$

$$\dot{I_2} = -\frac{-\dot{Z}_1 I_{L1} - (\dot{Z}_1 + \dot{Z_3})\dot{I_{L2}} + (\dot{V}_1 - \dot{V}_2)}{\dot{Z_{LOOP}}} \tag{1}$$

$$\dot{I_3} = -\frac{-\dot{Z}_1 I_{L1} + \dot{Z}_2 \dot{I_{L2}} + (\dot{V}_1 - \dot{V}_2)}{\dot{Z_{LOOP}}}$$

Where

$$\dot{Z_{LOOP}} = \sum_{i=1}^{3} Z_i, R_{loop} = \dot{\sum}_{i=1}^{3} R_i, L_{loop} = \sum_{i=1}^{3} L_i \tag{2}$$

As per the line loss minimization hypothesis theory in the loop distribution system, the line streams can be separated into two streams. The first is the present stream in every line during the line loss least condition [Iÿmi, (i = 1, 2, 3)], and the second one is the circle current Iÿloop that flows in the loop lines, as appeared in Fig. 2. Along these lines, the line current can be

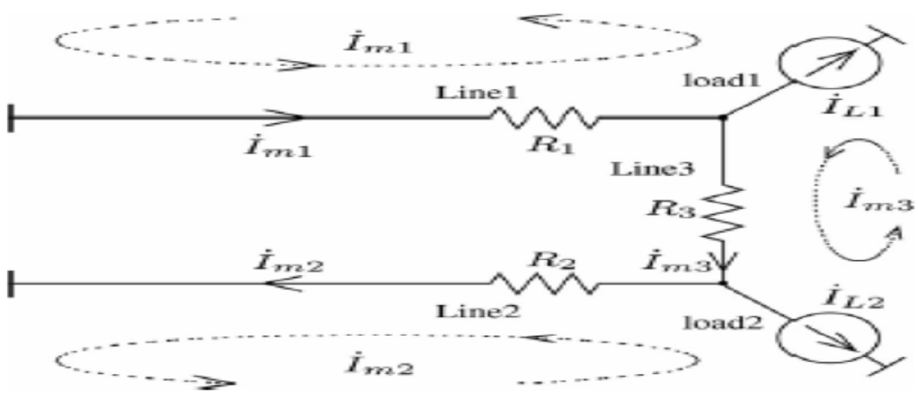


Figure 3: Equivalent circuit of the loop system under line loss minimization

Formulated as follows:

$$\dot{I_i} = \dot{I_{mi}} + \dot{I_{LOOP}} \tag{3}$$

The line streams that stream in every line of the loop system during line loss minimization, [İmi, (i = 1, 2, 3)], can be defined as takes after:

$$\dot{I_{m1}} = \{(R_2 + R_3)\dot{I_{L1}} + R_2\dot{I_{L2}}\}/\dot{I_{m2}}$$
$$\dot{I_{m2}} = \{-R_1\dot{I_{L1}}-(R_1 + R_3)\dot{I_{L2}}\}/R_{loop} \tag{4}$$
$$\dot{I_{m3}} = \{-R_1\dot{I_{L1}}+R_2\dot{I_{L2}}\}/R_{loop}$$

Considering the voltage difference in substations, the circle current Iÿloop that circles in the loop system lines can be defined as takes after:

$$\dot{I_{LOOP}} = -\frac{1}{R_{loop}}\{\sum_{i=1}^{3} j\omega L_i \dot{I_i} + (\dot{V_2} - \dot{V_1})\} \tag{5}$$

The total power loss in the isolated substation loop system lines can be formulated as follows:

$$P_l = \sum_{i=1}^{3} R_i\, |\dot{I}_i|^2$$
$$= \sum_{i=1}^{3} R_i\, |\dot{I}_{mi}|^2 + 2\left\{\sum_{i=1}^{3} (R_i \dot{I}_{mi})\right\}\dot{I}_{loop}$$
$$+ R_{loop}\, |\dot{I}_{loop}|^2$$

As per (6), the line loss minimum condition can be accomplished in the loop system if the loop current I˙Loop is disposed of from the system. For this situation, the line streams that stream on the up and up lines subsequent to taking out the circle current are [I˙mi, (i = 1, 2, 3)]. Fig. 3 demonstrates the comparable circuit of the disconnected loop distribution system if there should arise an occurrence of line loss minimization. In this manner, the resultant total line loss can be figured as takes after:

$$P_{lmin} = \sum_{i=}^{3} R_i|i_{mi}|\hat{}2 \tag{7}$$

The line loss minimum conditions can be obtained by equating the loop current, shown in (5) with zero, as follows:

$$\sum_{i=1}^{3} jw\, L_i \dot{I_i} + (\dot{V_2} - \dot{V_1}) = 0 \tag{8}$$

The loop current can be disposed of from the loop system if the summations of the reactance voltage drop notwithstanding the voltage distinction between the substation voltages measures up to zero. The summation of the reactance voltage drop squares with zero if the resistance to-inductance proportion in every line of the loop system is the same. Subsequently, the loop current can be eliminated from the loop system if the accompanying conditions have been figured it out, all the while:

$$R_1/L_2 = R_3//L_1 = R_2/L_3 \tag{9}$$
$$\dot{V_2} - \dot{V_1} = 0$$

(B) After Installing the UPFC for Line Loss Minimization

The UPFC is introduced in an isolated substations loop system with a specific end goal to dispose of the circle current from the system by inserting a controlled series voltage that can remunerate the contrast between substation voltages notwithstanding the summation of the reactance voltage drop in loop lines. With a specific end goal to compensate the summation of the reactance voltage drop, two control plans are proposed in light of (8) and (9). These control plans are line inductance compensation and line voltage pay. Both plans have a typical part that is utilized to repay the contrast between the substation voltages.

In the line voltage pay plot, the series converter voltage of the UPFC can be defined as takes after:

$$\dot{V_c} = \sum_{i=1}^{3} jw\, L_i \dot{I_i} + (\dot{V_2} - \dot{V_1}) \tag{10}$$

As a function of time, the UPFC series converter voltage can be formulated as follows:

$$v_c = \sum_{i=1}^{3} \mathrm{L_i} \frac{\mathrm{di_1}}{\mathrm{dt}} + (v_2 - v_1) \tag{11}$$

In the line inductance compensation plot, the UPFC is used to insert a virtual inductance, Lc, which acknowledges same proportion between the resistance and inductance in every line of the loop system. The embedded inductance Lc can understand the same resistance to-inductance proportion on the up and up system as takes after:

Therefore, the inserted inductance Lc can be calculated as follows:

$$\mathrm{L_c} = \left(\frac{R_1}{R_2}\right) \mathrm{L_2}\text{-}\mathrm{L_1} \tag{12}$$

In the line inductance compensation plot, the UPFC is used to insert a virtual inductance, Lc, which acknowledges same proportion between the resistance and inductance in every line of the loop system. The embedded inductance Lc can understand the same resistance to-inductance proportion on the up and up framework as takes after:

$$\dot{V_c} = -\jmath w \mathrm{L_c} \dot{I_1} + (\dot{\mathrm{V}}_2 - \dot{\mathrm{V}}_1) \tag{13}$$

As a function of time, the UPFC series converter voltage can be formulated as follows:

$$v_c = -\mathrm{L_c} \frac{\mathrm{di_1}}{\mathrm{dt}} + (v_2 - v_1) \tag{14}$$

It is clear that the line inductance compensation scheme can be used in the loop distribution system if there is only one line

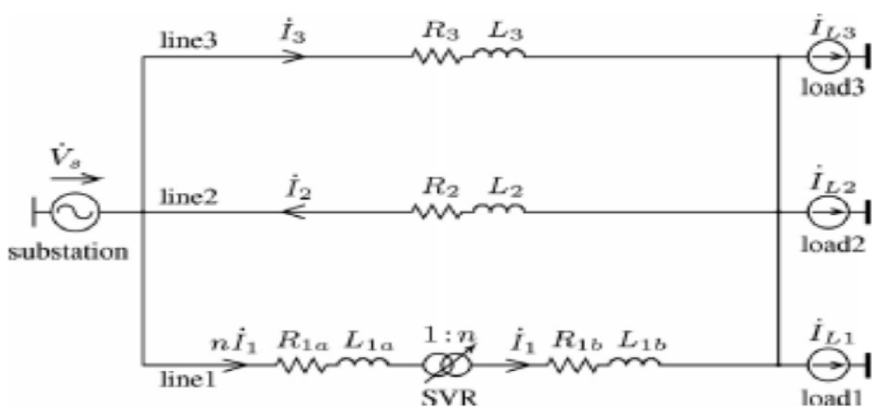


Figure 4: Model of the multiple loop distribution system

That has a different resistance to-inductance proportion. Along these lines, just this line current notwithstanding the substation voltages are required to obtain the reference voltage of the UPFC arrangement converter. Then again, the line voltage pay plan can be utilized as a part of the circle system if the resistance-to inductance proportion is not the same in, no less than, two lines of the loop. Likewise, in both plans, the line loss least condition does not require the load data. Both plans depend on loop line streams notwithstanding line impedance parameters to achieve Line misfortune minimization. In this manner, the system execution will not be influenced by load type.

III. MODEL OF THE SAME SUBSTATION MULTIPLE LOOP DISTRIBUTION SYSTEM WITH THE UPFC

Fig. 4 demonstrates the model of the same substation numerous loop dispersion system. It comprises of three outspread feeders fed from the same substation. The loads nourished from the outspread lines are associated in parallel keeping in mind the end goal to acquire two adjoining loop systems. For scientific model improvement, the loads are expected to be contiguous. In this manner, the impedance parameters of the line associating them are ignored. Line 1 has a stage voltage controller (SVR), a typical device used to repay load voltages along conveyance feeders. It is expected that the UPFC is introduced in arrangement with line 1 to accomplish line loss minimization by controlling the loop current in the two contiguous loop systems. The line currents in loop lines ought to current in the same direction. Subsequently, it is expected that the currents I˙1 and I˙2 stream in the counter clockwise bearing, while the streams I˙2 and I˙3 flow in the clockwise direction.

(A) Before Installing the UPFC

Considering that the UPFC output voltage is zero, the three load streams (I˙L1, I˙L2, and I˙L3) can be lumped together in a single load current (I˙L). As per the area of the SVR in line 1, the line parameter will be resolved referred to the optional side. Fig. 5 demonstrates the comparable circuit of the various loop system, appeared in Fig. 4. The line currents in each feeder of the loop distribution system model, appeared in Fig. 5, Can be formulated as follows:

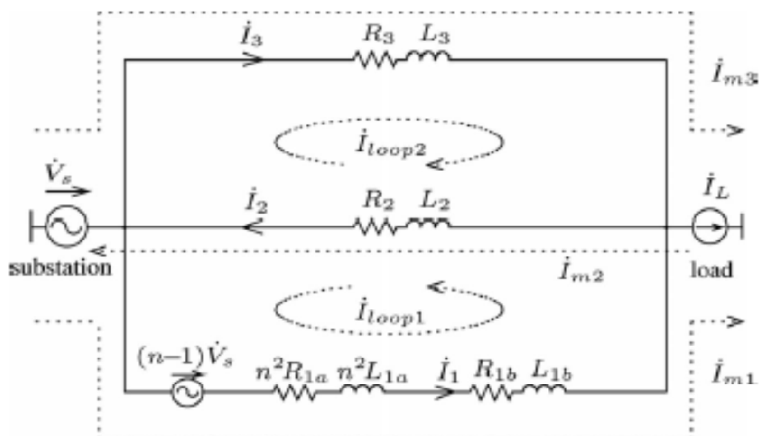


Figure 5: Equivalent circuit of the multiple loop system

Since the dispersion system is associated with perform two Adjacent loop systems, the line currents in every feeder can be isolated into the loop coursing currents (I˙loop1 and I˙loop2) in expansion to the currents at line loss least condition ([I˙mi , (i = 1, 2, 3)]). Along these lines, the line current can be defined as takes after:

The loop circulating current in each loop system can be formulated as follows:

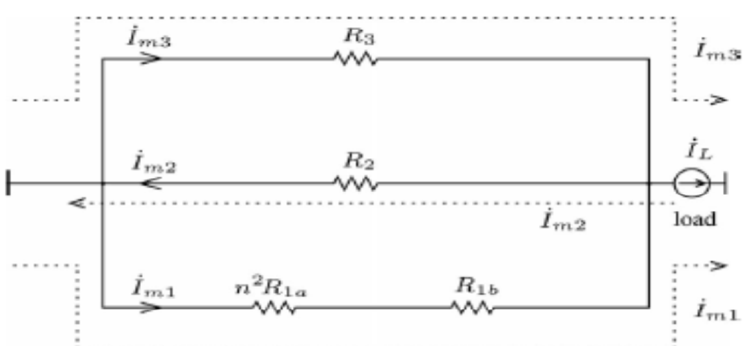


Figure 6: Equivalent model at line loss minimum condition

Based the loop current in each loop system ($I^{\cdot}$loop1 and $I^{\cdot}$loop2) can be formulated as follows:

In this case, the total power loss can be formulated as a function of the line currents and the loop currents as follows:

$$P_l = \sum_{i=1}^{3} R_i |\dot{I}_i|^2 \tag{15}$$

$$=\sum_{i=1}^{3} R_i |\dot{I}_{mi}|^2 + 2(R_1 \dot{I}_{mi} + R_2 \dot{I}_{m2}).\dot{I}_{loop1}$$

$$+2(R_2 \dot{I}_{m2} + R_3 \dot{I}_{m3}).\dot{I}_{loop2} + R_1 |\dot{I}_{loop1}|^2$$

$$+R_2 |\dot{I}_{loop1} + \dot{I}_{loop2}|^2 + R_3 |\dot{I}_{loop2}|^2 \tag{16}$$

As indicated by (16), the line losses least condition can be accomplished if both circle streams (I˙loop1 and I˙loop2) are dispensed with from the system. For this situation, the resultant total power loss can be detailed as takes after:

$$P_{lmin} = \sum_{i=1}^{3} R_i |\dot{I}_{mi}|^2 \tag{17}$$

It is clear from that eliminating out both loop currents from the loop system, with a specific end goal to acknowledge line loss minimum condition, can be accomplished if the accompanying two conditions are figured it out, at the same time:

(B) After Installing the UPFC for Line Loss Minimization

The main objective of introducing the UPFC in the same substation different loop appropriation framework is to understand the line loss least condition by controlling the circle influence stream, utilizing the series pay plan, gave by the embedded controlled series converter voltage. Fig. 7(a) demonstrates the different circle dissemination system with the UPFC in the event of line loss minimization. The voltages (V1, V2, and V3) speak to the inductive voltage drop in every (Line 1, Line 2, and Line 3). Utilizing Thevenin's hypothesis, the system can be approximated as appeared in Fig 7 (b) and (c) with a specific end goal to get the reference voltage of the UPFC series converter. The parallel feeders (Line 2 and Line 3) are approximated by a resistor ˙Z0 in series with a voltage source ÿV 0, which can be defined as takes after:

As indicated by the approximated loop system appeared in Fig. 7, the reference voltage of the UPFC series converter can be formulated as takes after:

$$V_c = V_1 + V_0 - (n-1)\, V_s \tag{18}$$

In this way, inserting a controlled arrangement voltage by the UPFC series converter as given in results in loop currents $\dot{I}'_{loop1}$ also, $\dot{I}'_{loop2}$ to be as per the following:

Where

Since the two loops are nearby, the circle currents $\dot{I}'_{loop1}$ and $\dot{I}'_{loop2}$ influence each other. The inserted controlled series voltage can dispense with the loop current $\dot{I}'_{loop1}$,which decreases the loop current $\dot{I}'_{loop2}$. Be that as it may, the loop current $\dot{I}'_{loop2}$ can be disposed of, all the while with the loop current $\dot{I}'_{loop1}$, if its loop lines have the same resistance to-inductance proportion. The reference voltage of the UPFC series converter can be detailed, as a component of time and line parameters, as takes after:

$$v_c = -L_c \frac{di_1}{dt} + \frac{R_3}{R_2 + R_3} L_2 \frac{di_2}{dt}$$

$$-\frac{R_2}{R_2+R_3}L_3\frac{di_3}{dt}-(n-1)v_s \tag{19}$$

In view of the line loss least conditions in both isolated substations what's more, same substation different loop distribution system, obviously the controlled series voltage depends predominantly on the line currents or line parameters. The adjustment in line parameters because of the temperature is little and it will be taking all things together line parameters, all the while. Consequently, it won't influence the system execution.

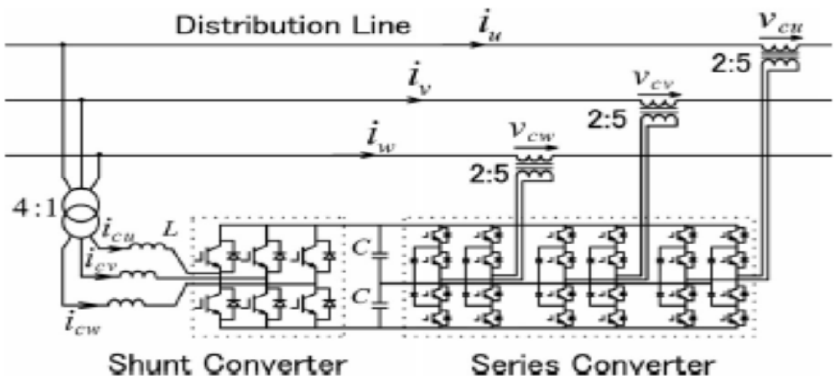


Figure 7: Configuration of the UPFC

Loop system is troublesome. Line currents on top of it system can be assessed as given. Additionally, the assurance plans of the loop system include another test in the practical system. Since the short out current in circle dispersion systems is high, late research works concentrate on protective devices for issue seclusion and fault location detecting methods.

IV. FUZZY LOGIC

Fuzzy rationale is a type of numerous esteemed rationales in which reality estimations of variables might be any genuine number somewhere around 0 and 1. By differentiation, in Boolean rationale, reality estimations of variables may just be 0 or 1. Fuzzy rationale has been stretched out to handle the idea of halfway truth, where reality quality may extend between totally genuine and totally false. Besides, when etymological variables are utilized, these degrees might be overseen by particular capacities.

The fuzzy rationale investigation and control strategies appeared in Figure 1 can be depicted as:

1. Receiving one or expansive number of estimations or other appraisal of conditions existing in some system that will be dissected or controlled.

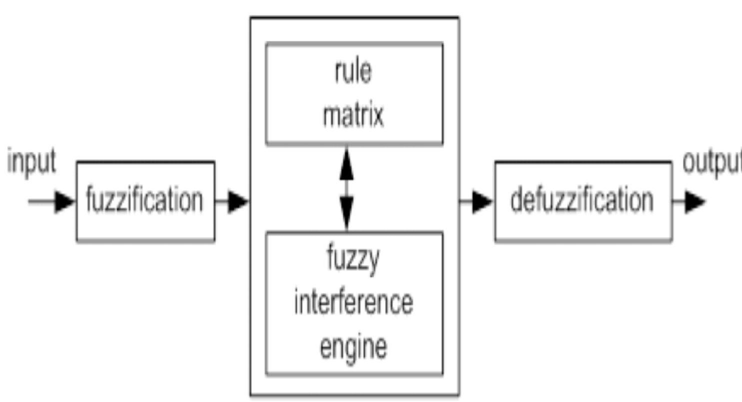


Figure 8: Schimatic diagram of fuzzy controller

2. Processing all got inputs as indicated by human based, fuzzy “assuming then” standards, which can be communicated in basic dialect words, and consolidated with conventional non-fuzzy preparing.
3. Averaging and weighting the outcomes from all the individual principles into one single output choice or sign which chooses what to do or advises a controlled system what to do. The outcome output sign is an exact defuzzified esteem. First of all, the different level of output (high speed, low speed etc.) of the platform is defined by specifying the membership functions for the fuzzy sets.

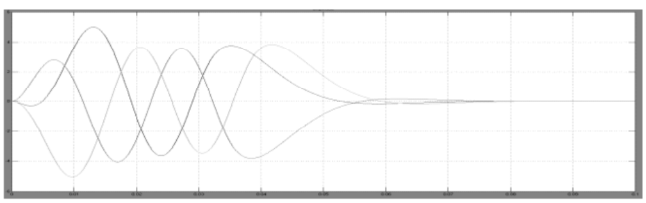
Table II
Rule base for Fuzzy logic controller

Input 2 *Input 1*	*nb*	*nm*	*ns*	*zr*	*Ps*	*Pm*	*pb*
nb	nb	nb	nb	nm	Nm	Ns	Zr
nm	nb	nb	nm	nm	Ns	Zr	Ps
ns	nb	nm	nm	ns	Zr	Ps	Pm
zr	nm	nm	ns	zr	Ps	Pm	Pm
ps	nm	ns	zr	ps	Pm	pm	Pb
pm	ns	zr	ps	pm	Pm	pb	Pb
pb	zr	ps	pm	pm	Pb	pb	Pb

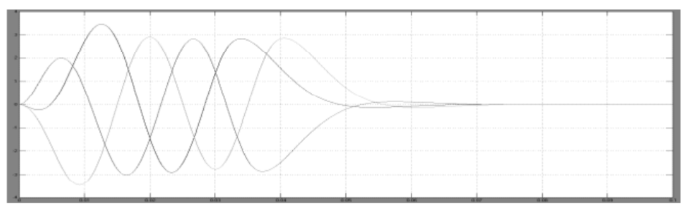
SIMULATION RESULTS

Loop1 & Loop 2 currents in multiple loop distribution system using UPFC with PI&FUZZY controller.

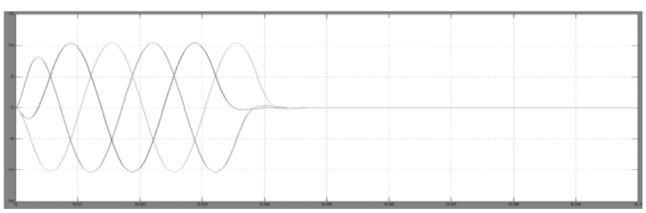
Performance comparison of PI and FUZZY controller is given in below table.



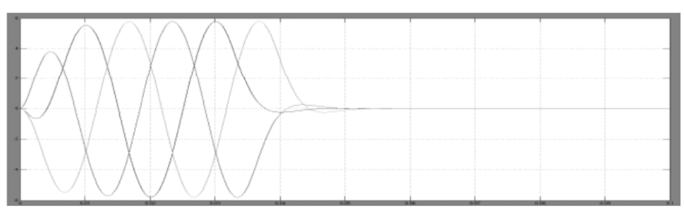
Loop 1 current with PI controller



Loop 2 current with PI controller



Loop 1 current with fuzzy controller



Loop 2 current with fuzzy controller

Table I
Performance comparison of PI and FUZZY controller

		Multiple Loop with Out UPFC	*Multiple Loop with UPFC (PI Controller)*	*Multiple Loop with UPFC (fuzzy Controller)*
Settling time(sec)	LOOP1	No controller	0.06-0.07	0.04-0.05
	LOOP2	No controller	0.06-0.07	0.05
THD(%)	LOOP1	No controller	32.64	29.78
	LOOP2	No controller	34.34	30.81

V. CONCLUSION

This paper has exhibited the line loss least condition what's more, the power flow control plans of the UPFC to acknowledge line loss minimization in the disengaged substations and the same substation numerous circle dissemination systems, alongside with a detailed scientific investigation of both systems. The line misfortune least condition has been acknowledged tuned in dissemination system by repaying the line reactance voltage drop notwithstanding the distinction of substation voltages on account of disconnected substations circle system. Two control plans of the UPFC series converter have been proposed to accomplish line misfortune least condition in loop systems. These control plans are the line inductance pay and line voltage pay. A correlation amongst exploratory and hypothetical results has been introduced to assess the precision of the outcomes and the validity of line loss minimum condition theory.

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