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OPTIMAL POWER FLOW ANALYSIS USING FACTS DEVICES

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ABSTRACT
In spite of a large discipline regarding FACTS (flexible AC transmission system) analysis and implementation, a very limited amount of contributions in open literature investigate the economics of these devices. The present paper focuses on the implementation of UPFC with two back-to-back VSCs with a common dc-terminal capacitor. Comparison has been done using MATLAB Simulink for Bus Voltages of IEEE 30 bus System without and with UPFC. The obtained outcomes indicate that SGA is a simple to utilize, hearty, and powerful enhancement strategy compared with N-R technique and SGA without UPFC.

Keywords: Optimal power flow (OPF), FACTS Devices (SVC), STATCOM and SGA.

1. INTRODUCTION

The electricity supply industry is enduring a profound transformation worldwide. Market forces, scarcer natural resources and a regularly developing mandate for electricity is a portion of the drivers at risk for such an extraordinary change. Against this group of rapid development, the expansion programs of many utilities are being disappointed by an assortment of well-established, natural, land use and administering loads that maintain a strategic distance from the permitting and working of new transmission lines and electricity producing units. A top to bottom analysis of the determinations accessible for amplifying present transmission resources, with abnormal amounts of dependability and stability, has pointed toward power electronics. There is common understanding that novel power electronics hardware and strategies are potential substitutes for customary arrangements, which depend on electro-mechanical technologies that have slow response times and high maintenance costs.

The power electronics options we have are HVDC transmission systems and FACTS. Till recently, active and reactive power control in AC transmission networks was prepared by reasonably managing transmission line impedances, additionally controlling terminal voltages by generator excitation control and by transformer tap varieties. On occasion, series and shunt impedances were locked in to proficiently change line impedances. FACTS technology is most fascinating for transmission planners since it opens up new chances for controlling power and improving the usable capacity of the present, just as new and advanced lines.

The likelihood that current through a line can be controlled at a reasonable expense empowers an important capability of expanding the capacity of present lines with huge conductors and utilization of one of the FACTS controllers, to empower reliable power to flow through such lines under normal and possibility conditions. By giving included adaptability, FACTS controllers can allow a line to pass on power nearer to its thermal rating. It must be featured that FACTS is an allowing technology, not a balanced substitute for mechanical switches.

In its most broad articulation, the FACTS thought depend on the impressive combination of power electronic devices and strategies into the high-voltage side of the network, to make it electronically controllable. Comprehensive modeling of most broad FACTS devices specifically SVC, TCSC, STATCOM and UPFC for power flow studies is endorsed. The proficiency of modeling and assembly is checked on a five transport system with no FACTS devices and further inspected it with various FACTS devices. The Newton-Raphson strategy is utilized to determine the nonlinear power flow condition. The work is additionally extended to IEEE 30 transport system.

2. UNIFIED POWER FLOW CONTROLLER

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A combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) which are joined by means of a common dc interface, to allow bi-directional flow of genuine power among the series yield terminals of the SSSC and the shunt worked terminals of STATCOM, and are controlled to offer concurrent genuine and reactive series line compensation without an outside electric vitality source. The UPFC, by means of angularly unhampered series voltage infusion, can control, simultaneously or selectively, the transmission line voltage, impedance and angle or on the other hand, the genuine and reactive power flows in the line. The UPFC may likewise offer independently controllable shunt reactive compensation.

The UPFC which is one of the most promising devices in the FACTS concept has been researched and put into practical use.

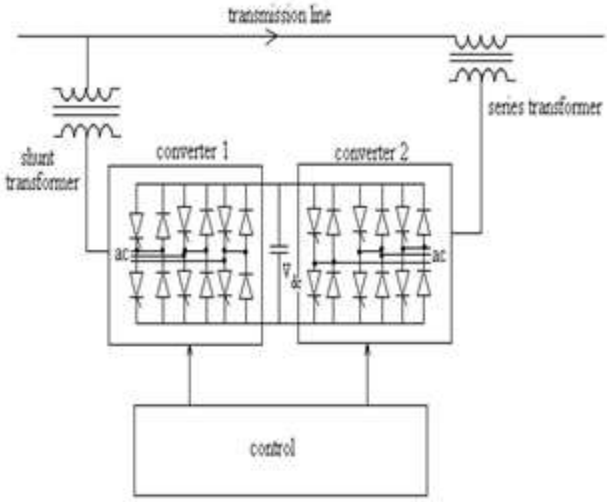

Figure-1.1: The implementation of UPFC with two back-to-back VSCs with a common dc-terminal capacitor

The UPFC contains of two voltage source converters. The dc voltage for the two converters is offered by a common capacitor bank (dc connect) (Figure 4.9). Converter 2 offers the principle capacity of the UPFC by embeddings an AC voltage with controllable extent Vpq, in series with the transmission line through a series transformer which can be changed from 0 to Vpqmax and stage angle of Vpq can be independently ranged from 0o to 360o. The fundamental capacity of converter 1 is to supply or draw in the genuine power demand of converter 2 which it gets from the transmission line itself. While the reactive power is inside made/absorbed by the series converter, the genuine power generation/absorption is made doable by the dc vitality storage device, i.e., the capacitor. It can likewise make or absorb controllable reactive power and offer independent shunt reactive compensation for the line. Converter 2 supplies or connects locally the required reactive power and exchanges the active power because of the series infusion voltage.

In this manner the genuine net power drawn from the AC system is equivalent to the loss of the two converters and their coupling transformers. Additionally, the shunt converter capacities like a STATCOM and self-sufficiently control the terminal voltage of the bound together transport.

2.1 POWER FLOW STUDIES

Planning the activity of power systems under current conditions, its enhancement and likewise its future expansion require the heap flow contemplates, short circuit studies and stability thinks about. The satisfactory activity of the system depends upon significant the impacts of interconnections, new loads, new producing stations and new transmission lines prior they are introduced. They additionally help to characterize the best size and favorable locations for the power capacitors both for the development of the power factor and likewise raising the transport voltages of the electrical network. Through the heap flow considers, we can get the voltage sizes each transport in the enduring state. This is fairly important, as the extents of the transport voltages are basic to be confined inside an expressed utmost. After the transport voltage sizes and their angles are intended by means of the heap flow, the genuine and reactive power flow

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through each line can be determined. So also dependent on the contrast between power flow in the transferring and getting ends, the misfortunes on a specific line can likewise be determined.

2.1.1 Search Group Algorithm

In order to bargain designs which are nearer to the worldwide ideal of the issue expressed in Eq. (1.1), the proposed algorithm goes for having a legitimate balance between the exploration and abuse of the plan domain. In fact, the manner which a new distinct is produced what makes it feasible for the SGA to understand this objective. The fundamental idea is that in the initial emphasess of the improvement procedure the SGA efforts to find promising locales on the domain (exploration), and as the cycles cruise by, the SGA refines the best structure in each of these skilled districts (misuse). It is the annoyance constant defined in Segment 1.4 that controls this method.

Likewise, a mutation operator is utilized to make new designs from the ones of the current inquiry gathering. Likewise, the generation of new individuals is followed distinctly by a couple of individuals from the populace, which is called here the pursuit gathering. In this manner, the SGA is included of five stages: the initial populace, initial inquiry bunch choice, and mutation of the hunt gathering, generation of the families and choice of the new pursuit gathering. In the following subsets, each progression of the algorithm is clarified in detail.

2.1.2 Initial Population

The initial population P is generated arbitrarily in the search domain:

$$P_{ij} = X_j^{min} + \left(X_j^{max} - X_j^{min}\right)U[0,1] \qquad j=1 \text{ to } n, \quad i=1 \text{ to } n_{pop}, \tag{1.1}$$

Where Pij is the jth design variable of the ith individual of the population P, U[0, 1] is a uniform random variable which ranges from 0 to 1, Xminj and Xmaxj are the lower and upper bounds of the jth design variable, correspondingly, n is the number of design variables and npop is the size of the population. As it can be seen in Eq. (4), each row of P signifies an individual of the population and each column signifies a design variable.

2.1.3 Initial Search Group Selection

After the initial population P is created, the target capacity of each individual is assessed. Figure 2 demonstrates this progression by giving size to the individuals according to the estimation of their goal capacities, for example the greater the circle is, the better the target capacity of the individual is. After the target capacities are assessed, the pursuit bunch R is worked by selecting ng individuals from P. A standard tournament determination is connected to seek after this progression of the algorithm. More details about the tournament choice might be found. A case of the chose individuals is shown in Figure 3.

As the population P, each column of R speaks to an individual, for example Ri; speaks to the ith line of R and subsequently the ith individual from the hunt gathering. It is important to point around here that the individuals from the hunt gathering are ranked after each emphasis of the algorithm, for example R1; is dependably the best structure and Rng; is dependably the worst plan among the inquiry bunch individuals.

2.1.4 Generation of the Families of Each Search Group Member

Here, we name family the set comprised of each member of the search group and the individuals that it generated, and we denote each family by Fi, where i = 1 to ng. So, once the search group is made, each one of its members makes a family by the perturbation described in Equation (1.2),

$$x_j^{new} = R_{ij} + \alpha\varepsilon, \qquad \text{for} \qquad j=1,\ldots,n, \tag{1.2}$$

Where a controls the size of the perturbation Here, we propose the reduction of the parameter a at each iteration k of the search process. The update of this parameter is given by:

$$\alpha^{k+1} = b\alpha^{k}, \tag{1.3}$$

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Where b is a parameter of the SGA

2.2 SELECTION OF THE NEW SEARCH GROUP

As mentioned in the opening of this segment, the proposed algorithm is included of two stages: the worldwide and nearby stages. In the principal it worldwide max emphases, which we call here the worldwide stage, the main fair of the algorithm is to explore the greater part of the structure space. Afterward, the new inquiry gathering is made by the best individual from each family. At the point when the cycle number is higher than it max worldwide, the choice system is improved: the new hunt gathering is made by the best n g individuals among every one of the families. This stage is named nearby since the algorithm will incline to deed the locale of the current best plan.

2.2.1 Further comments on the SGA

The SGA may be seen as a general evolutionary approach. The points that make the SGA different from other algorithms are:

- The strategy that the improved the search group member is, the more entities it generates in a given iteration;
- The proposed mutation approach based on the mean value and normal deviation of the position of the current search group members in a specified iteration;
- The proposed scheme for the selection of the next search group: global phase (the new search group is formed by the best member of each family) and local phase (the new search group is trained by the best ng individuals among all the families).

A second feature that is worth stating is the setting of the SGA parameters. The parameters of the algorithm may differ conferring to the characteristics of the problematic to be solved.

For example, for more stimulating problems, usually the algorithm needs to raise its exploration capability to avoid local minima. Hence, the designer must have in mind the characteristics of the optimization problematic in order to evaluate proper value for the SGA parameters, setting the ratio between the exploration and exploitation of the algorithm. To make this process easier for the reader, we list below the SGA parameters and summarize their purposes in the optimization process:

n pop: number of individuals in the population, it is kept constant during all the optimization process; itmax: maximum number of iterations, employed in all the examples as stopping criterion. Together with npop, it defines the computational cost/time that the designer has to the optimization process; domain, i.e. the more function evaluations are employed to find promising regions. Its value varied in the examples between 0.2 to 0.9, and normally; itmax global: maximum number of iterations of the global phase (exploration phase). The closer to one this parameter is, the more iterations are dedicated to the exploration of the design

2.2.2 Pseudo Code of the SGA

To make it easier for the reader the implementation of the SGA, it is given below a step-wise algorithm of the proposed optimization method:

Step 1: Initialize the parameters of the proposed algorithm: k = 0, itmax, itmaxglobal; . k, min, b, npop, ng, nmut, h, t, and ;

Step 2: Generate the initial population P;

Step 3: Create the initial search group Rk selecting ng individual from the initial population using a tournament selection;

Step 4: Replacement individuals by new members created as described in Equation 5;

Step 5: Generate the families Fi using Equation (6);

Step 6: Select the new search group according to the rule:– If k < itmaxglobal: search group Rk+1 is formed by the best member of each family;

– Otherwise: search group Rk+1 is formed by the best ng individuals of the population.

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Step 7: Update k1 accordingly to Eq. (7);

Step 8: Make k = k+1, if k itlmax, go to Step 9, otherwise return to Step 4;

Step 9: Solution found: x* = R1.In the next section, six truss optimization benchmark problems are solved to show the effectiveness of the SGA.

Table-2.1: SGA Parameter

Alpha min	0.1
Initial Alpha	0.5
No of Population	50
Maximum Iteration	100

3. POWER FLOW MODEL OF UPFC

The equal circuit involves of two coordinated synchronous voltage sources ought to imply the UPFC satisfactorily for the motivation behind fundamental frequency steady state analysis. Such a comparable circuit is appeared in Figure 3.1

The UPFC voltage sources are as follows:

$$E_{vR} = V_{vR}\left(\cos\delta_{vR} + j\sin\delta_{vR}\right) \quad (1.4)$$

$$E_{cR} = V_{cR}\left(\cos\delta_{cR} + j\sin\delta_{cR}\right) \quad (1.5)$$

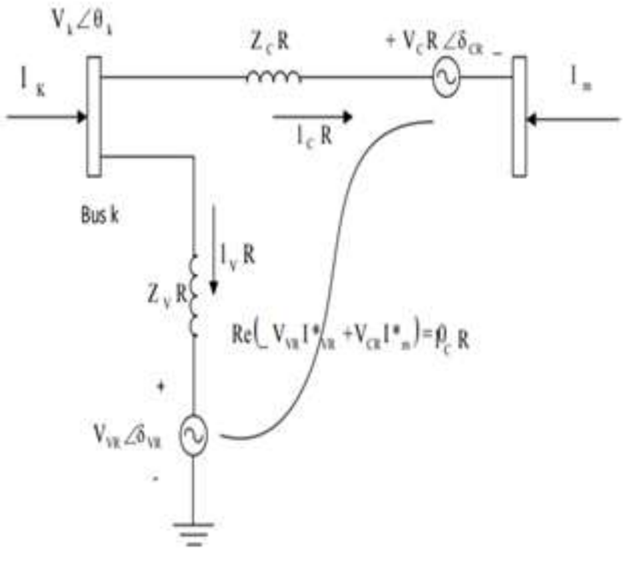

Figure-3.1: UPFC equivalent circuits

Where VvR and vR are the controllable magnitude (VvRmin VvR V vRmax) and phase angle (0 vR) of the voltage source representing the shunt converter. The magnitude VcR and phase angle cR of the voltage source in place of the series converter are controlled among confines (VcRmin VcR VcRmax) and (0 cR), respectively. The stage angle of the series inserted voltage defines the method of power flow control. On the off chance that cR is in stage with the nodal voltage angle k, the UPFC controls the terminal voltage. On the off chance that cR is in quadrature with k, it controls active power flow, temporary as a stage shifter. On the off chance that cR is in quadrature with line current angle, then it controls active power flow, temporary as a variable series compensator. At any other estimation of cR, the UPFC works as a combination of the voltage regulator, variable series compensator, and stage shifter. The greatness of the series inserted voltage manages the measure of power flow to be controlled.

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In view of the proportionate circuit appeared in Figure 4.16 and Conditions (4.53) and (4.54), the active and reactive power conditions at transport k are as follows:

$$\begin{aligned} P_k &= V_k^2 G_{kk} + V_k V_m [G_{km}\cos(\theta_k - \theta_m) + B_{km}\sin(\theta_k - \theta_m)] \\ &. + V_k V_{cR} [G_{km}\cos(\theta_k - \delta_{cR}) + B_{km}\sin(\theta_k - \delta_{cR})] \\ &+ V_k V_{vR} [G_{vR}\cos(\theta_k - \delta_{vR}) + B_{vR}\sin(\theta_k - \delta_{vR})] \end{aligned} \quad (1.6)$$

$$\begin{aligned} Q_k &= -V_k^2 B_{kk} + V_k V_m [G_{km}\sin(\theta_k - \theta_m) - B_{km}\cos(\theta_k - \theta_m)] \\ &+ V_k V_{cR} [G_{km}\sin(\theta_k - \delta_{cR}) - B_{km}\cos(\theta_k - \delta_{cR})] \\ &+ V_k V_{vR} [G_{vR}\sin(\theta_k - \delta_{vR}) - B_{vR}\cos(\theta_k - \delta_{vR})] \end{aligned} \quad (1.7)$$

At bus m

$$\begin{aligned} P_m &= V_m^2 G_{mm} + V_m V_k [G_{mk}\cos(\theta_m - \theta_k) + B_{mk}\sin(\theta_m - \theta_k)] \\ &+ V_m V_{cR} [G_{mm}\cos(\theta_m - \delta_{cR}) + B_{mm}\sin(\theta_m - \delta_{cR})] \end{aligned} \quad (1.8)$$

$$\begin{aligned} Q_m &- V_m^2 G_{mm} + V_m V_k [G_{mk}\sin(\theta_m - \theta_k) - B_{mk}\cos(\theta_m - \theta_k)] \\ &+ V_m V_{cR} [G_{mm}\sin(\theta_m - \delta_{cR}) + B_{mm}\cos(\theta_m - \delta_{cR})] \end{aligned} \quad (1.9)$$

Series converter

$$\begin{aligned} P_{cR} &= V_{cR}^2 G_{mm} + V_{cR} V_k [G_{mk}\cos(\theta_m - \theta_k) + B_{mk}\sin(\theta_m - \theta_k)] \\ &+ V_m V_{cR} [G_{mm}\cos(\theta_m - \delta_{cR}) + B_{mm}\sin(\theta_m - \delta_{cR})] \end{aligned} \quad (1.10)$$

$$\begin{aligned} Q_m &- V_m^2 G_{mm} + V_m V_k [G_{mk}\sin(\theta_m - \theta_k) - B_{mk}\cos(\theta_m - \theta_k)] \\ &+ V_m V_{cR} [G_{mm}\sin(\theta_m - \delta_{cR}) + B_{mm}\cos(\theta_m - \delta_{cR})] \end{aligned} \quad (1.11)$$

Shunt converter

$$P_{vR} = -V_{vR}^2 G_{vR} + V_{vR} V_k [G_{vR}\cos(\delta_{vR} - \theta_k) + B_{vR}\sin(\delta_{vR} - \theta_k)] \quad (1.12)$$

$$Q_{vR} = V_{vR}^2 B_{vR} + V_{vR} V_k [G_{vR}\sin(\delta_{vR} - \theta_k) - B_{vR}\cos(\delta_{vR} - \theta_k)] \quad (1.13)$$

$$P_{vR} + P_{cR} = 0 \quad (1.14)$$

Assuming lossless converter values, the active power supplied to the shunt converter, PvR, equals the active power demanded by the series converter,

PcR; that is, Furthermore, if the coupling transformers are assumed to contain no resistance, then the active power at bus k matches the active power at bus m. accordingly,

$$P_{vR} + P_{cR} = 0 \quad (1.15)$$

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The UPFC power equations are combined with those of the AC network.

4. RESULTS FOR IEEE 30 BUS SYSTEMS:

The IEEE-30 transport network is adjusted to include UPFC to compensate the transmission line issue for transport 25 and 26 individually. UPFC ought to maintain genuine and reactive power flowing in words the transports. The UPFC shunt Converter is set to direct the modal voltage magnitude at transport 25 at 1 p.u.

Table-4.1: Bus voltages of IEEE 30 bus System without and with UPFC.

Bus. No	Voltage (p.u)		
	N-R method	SGA	SGA with UPFC at bus 25
1	0.982	1.06	1.06
2	0.979	1.043	1.043
3	0.977	1.025	1.027
4	0.976	1.017	1.019
5	0.971	1.01	1.01
6	0.972	1.015	1.017
7	0.962	1.005	1.006
8	0.961	1.01	1.01
9	0.99	1.053	1.056
10	1	1.047	1.052
11	0.99	1.082	1.082
12	1.017	1.06	1.062
13	1.064	1.071	1.071
14	1.007	1.045	1.049
15	1.009	1.04	1.045
16	1.003	1.047	1.051
17	0.995	1.042	1.046
18	0.993	1.03	1.035
19	0.987	1.028	1.033
20	0.99	1.032	1.037
21	1.009	1.034	1.041
22	1.016	1.035	1.042
23	1.026	1.03	1.039
24	1.017	1.024	1.039
25	1.044	1.02	1.058
26	1.027	1.003	1.041
27	1.069	1.027	1.051
28	0.982	1.013	1.017
29	1.05	1.007	1.032
30	1.039	0.996	1.021

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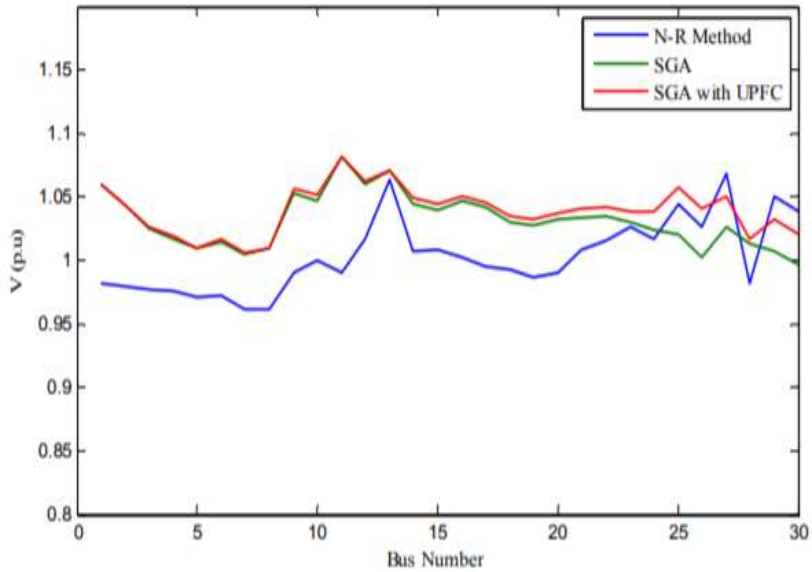

Figure-4.1: Bus Voltages of IEEE 30 bus System without and with UPFC.

Three unique approaches have been connected to improve transmission effectiveness of the proposed power system, are Newton-Raphson strategy and hunt bunch Algorithm and inquiry bunch Algorithm is the UPFC separately. Initially, the transport voltage solid with 0.98 p.u for N.R strategy, 1.06 p.u for SGA approach and 1.060 p.u for SGA in the UPFC and settled in the 1.039 p.u for SGA in the UPFC individually. The union is obtained in hundred cycles and the transport voltage is given in Table 4.2 The graphical analysis of the transport voltage in regard to transport number is appeared in Figure 4.4. From the Figure 4.4 It is seen that the blue line indicates power flow analysis for the IEEE 30 transport System performing in the Newton-Raphson technique, Green line indicates the power flow analysis in the inquiry Gathering Algorithm approached, and red line indicate the power flow analysis of proposed control strategy of SGA in the UPFC. From the united comparative transport voltage results demonstrate the proposed SGA in the UPFC approach is smarter to other proposed approach.

5 CONCLUSION

In this chapter, Inquiry Gathering algorithm has been proposed to take care of ideal power flow issue within the sight of bound together power flow controller. The outcomes show the viability and strength of the proposed strategy with bound together power flow controller. The outcomes found for IEEE 30 transport system using the proposed strategy without and with UPFC are compared, and perceptions uncover that the misfortunes are less with UPFC. In IEEE 30 transport system UPFC is situated between transport 25 and transport 26 the simulation results were taken, and it was recognized. Ideal power flows dependent on SGA algorithm with UPFC the system performance has been enhanced. The obtained outcomes indicate that SGA is a simple to utilize, hearty, and powerful enhancement strategy compared with N-R technique and SGA without UPFC.

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