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Enhancing the Stability Performance of Iraqi National Super Grid System by Using UPFC Devices Based on Genetic Algorithm

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ABSTRACT

The object of this work is to improve the stability of the Iraqi National Super Grid System (INSGS) by installing Unified Power Flow Controller (UPFC) devices in different optimal locations under fault condition and comparing the results with those of without FACTS under the same condition.The optimal location of the FACTS device was specified based on Genetic Algorithm (GA) optimization method, it was utilized to search for optimum FACT parameters setting and location based objective function that depends on the power and voltage as a fitness constraints.MATLAB was used for running both the GA program and Power System Analysis Toolbox (PSAT) as Graphical User Interface, Newton Raphson method also used for solving the load flow of the system and the Trapezoidal method for the non-linear differential equations.The system that has been implemented is INSGS 11-machine, 24-bus, 39 (400kV) overhead transmission lines.The GA program is applied for the Iraqi grid system which is complicated.The results obtained showed that the installation of UPFC devices at the optimal locations of the Iraqi grid gives an improvement in the stability by damping the voltage and rotor angle oscillations after subjected to the three phase fault to ground at different locations and different cases (temporary fault, permanent fault).A comparison has been made between these different cases based on the durations of the tested faults, and with the UPFC devices installed in the system, it can remain stable for longer time than without UPFC during fault condition.

Keywords: Unified Power Flow Controller (UPFC), Genetic Algorithm (GA), Power System Analysis Toolbox (PSAT)

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تحسين اداء الاستقرارية للشبكة الوطنية العراقية بواسطة إستخدام أجهزة (UPFC)إستنادا على الخوارزمية الوراثية

الخلاصة

الغرض من هذا العمل هو تحسين استقرارية منظومة القدرة للشبكة العراقية عن طريق نصب أجهزة الـ(FACTS) في أماكن مثالية مختلفة تحت ظرف الخطأ ومقارنة النتائج مع تلك التي لاتسخدم هذه الاجهزة في نفس الظروف.تم تحديد الموقع الأمثل لهذه الأجهزة إعتماداً على الصيغة الامثلية العامة تعرف بالخوارزميات الجينية (Genetic Algorithm), وتم استخدامها للبحث عن الخصائص والمواقع المثلى على أساس الدالة الموضوعية(Objective Function) التي تعتمد على القدرة والفولتية كمحددات(Fitness Function).تم استخدام برنامج الـ MATLAB لتشغيل كل من برنامج الـ(GA) والـ(PSAT) كواجهة رسم للمستخدم, كما تم أستخدام طريقة (Newton Raphson) لحل تدفق الحمل للنظام وطريقة (Trapezoidal) للمعادلات التفاضلية غير الخطية. وقد تم تنفيذ البرنامج على منظومة الشبكة الوطنية العراقية.تم تنفيذ برنامج الـ(GA) على منظومة الشبكة الوطنية العراقية.أظهرت النتائج التي تم التوصل إليها أن تركيب أجهزة الـ(UPFC) في المواقع المثلى للشبكة العراقية تؤدي إلى تحسين الأستقرارية عن طريق زيادة إخماد الترددات الحاصلة للفولتية وزاوية الدوار(Rotor Angle) بعد التعرض لخطأ من نوع (Three phase to ground) لحالات ومواقع مختلفة (خطأ مؤقت و خطأ دائم), وقد تم إجراء مقارنة بين هذه الحالات المختلفة إستناداً إلى فترات الأخطاء التي تم أختبارها, بالأضافة إلى ذلك ومع وجود أجهزة الـ(FACTS) يمكن للنظام أن يبقى مستقراً لفترة أطول من حالته بدون هذه الأجهزة بإستخدام نفس نوع الخطأ.

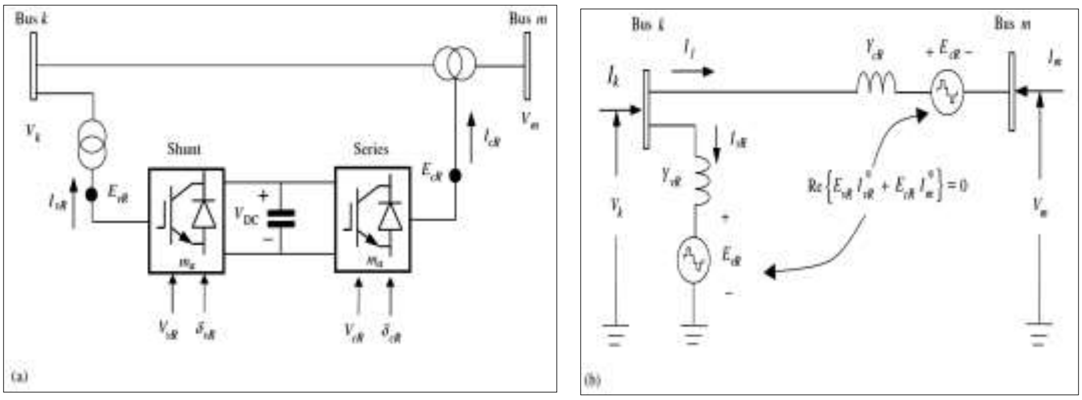
INTRODUCTION

Modern power system is a complex network comprising of numerous generators, transmission lines, variety of loads and transformers. As a consequence of increasing power demand, some transmission lines are more loaded than was planned when they were built. Stability depends upon both the initial operating conditions of the system and the severity disturbance [1]. Voltage Support is mainly important to decrease voltage changes at the terminals of a transmission path [2].In this paper the two main objectives are concerned:improve the voltage and angle profiles and minimize the system losses.In order to improve voltage and angle stability and reduce electromechanical oscillations in interconnected power systems for the development of power systems, especially the more important to control the power flow along the transmission line and according to the rapid growth in the development of solid state power electronics and advanced digital controllers that have been seen in the past three decades, all these lead to introduce the Unified Power Flow Controller (UPFC) [3].The major control functions of a UPFC are: (i) active power regulation; (ii) reactive power regulation; and (iii) voltage regulation. By combination of Static Synchronous Series Compensator (SSSC) and Static Compensator (STATCOM),the UPFC has unique advantage that it can control all of operational parameters of transmission system such as line impedance, voltage magnitude and phase [4].UPFC can be adjusted according the required characteristics where the UPFC can work as STATCOM to improve the network voltage profile by controlling the shunt elements of the UPFC only. Also, it can work as SSSC to improve the network lines loading by controlling the series element of the UPFC, only UPFC has the ability to do both of STATCOM and SSSC performance simultaneously [2].Genetic Algorithm (GA) has been used as optimizing the parameters of control system that are complex and difficult to solve by conventional optimization methods because GA combines the function evaluation with the randomized and/or well-structured exchange of information among the solutions to arrive at a global optimum. More importantly, GA appears attractive because of its superior robust behavior in nonlinear environments over the other optimization techniques [5].

MATHEMATICAL MODEL OF UPFC

A simplified schematic representation of the UPFC is given in Figure (1a), together with its equivalent circuit, in Figure (1b).

The UPFC allows simultaneous control of active power flow, reactive power flow, and voltage magnitude at the UPFC terminals. Alternatively, the controller may be set to control one or more of these parameters in any combination or to control none of them.



(a) **(b)**

Figure (1) Unified power flow controller (UPFC) system: (a) two back-to-back IGBT voltage source converters (VSCs), with one VSC connected to the AC network using a shunt transformer and the second VSC connected to the AC network using a series transformer; (b) equivalent circuit based on solid-state voltage sources.

The active power demanded by the series converter is drawn by the shunt converter from the AC network and supplied to bus m through the DC link. The output voltage of the series converter is added to the nodal voltage, at say bus k, to boost the nodal voltage at bus m. The voltage magnitude of the output voltage V_{cR} provides voltage regulation, and the phase angle δ_{cR} determines the mode of power flow control.

In addition to providing a supporting role in the active power exchange that takes place between the series converter and the AC system, the shunt converter may also generate or absorb reactive power in order to provide independent voltage magnitude regulation at its point of connection with the AC system.

The UPFC equivalent circuit shown in Figure (1b) consists of a shunt-connected voltage source, a series-connected voltage source, and an active power constraint equation, which links the two voltage sources. The two voltage sources are connected to the AC system through inductive reactance representing the VSC transformers. From Equation (1)

$$E_{vR}^{\rho}= V_{vR}^{\rho}(\cos\delta_{vR}^{\rho} + \mathrm{j}\sin\delta_{vR}^{\rho}) \qquad \dots (1)$$

A three-phase UPFC, suitable expressions for the two voltage sources and constraint equation would be:

$$\mathrm{Re}\left\{-E_{vR}^{\rho} I_{vR}^{*\rho} + E_{vR}^{\rho} I_{m}^{*\rho}\right\} = 0 \qquad \dots (2)$$

Similar to the shunt and series voltage sources used to represent the STATCOM and the SSSC, respectively, the voltage sources used in the UPFC application would also have limits.

UPFC is connected between two buses k and m in the power system. Based on the equivalent circuit shown in Figure (1b), assuming three-phase parameters and applying the kirchoff's current and voltage laws for the network in Figure (١b) gives the following transfer admittance equation:

$$\begin{bmatrix} \mathbf{I}_k \\ \mathbf{I}_m \end{bmatrix} = \begin{bmatrix} (\mathbf{Y}_{cR} + \mathbf{Y}_{vR}) & -\mathbf{Y}_{cR} & -\mathbf{Y}_{cR} & -\mathbf{Y}_{vR} \\ -\mathbf{Y}_{cR} & \mathbf{Y}_{cR} & \mathbf{Y}_{cR} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \mathbf{V}_k \\ \mathbf{V}_m \\ \mathbf{E}_{cR} \\ \mathbf{E}_{vR} \end{bmatrix} \dots (3)$$

Power flow (or load flow) analysis involves the calculation of power flows in lines/transformers and voltages of a power system for a given set of bus bar loads, active power generation schedule and specified bus voltage magnitude at generating buses. Such calculations are widely used in the analysis and design of steady state operation as well as dynamic performance of the system.

The power flow problem is formulated as a set of nonlinear equations. Many calculation methods have been proposed to solve this problem. Among them, Newton-Raphson (NR) method and fast-decoupled load flow method are two very successful methods. In general, the decoupled power flow methods are only valid for weakly loaded network with large X/R ratio network. For system conditions with large angles across lines (heavily loaded network) and with special control devices such as UPFC that strongly influence active and reactive power flows, NR method may be required [6].

From the circuit shown in Figure (1b), the UPFC voltage sources given in equations (1) V_{vR} andδ_{vR} are the controllable magnitude ($V_{vRmin} \leq V_{vR} \leq V_{vRmax}$) and phase angle ($0 \leq \delta_{vR} \leq 2\pi$) of the voltage source representing the shunt converter. The magnitude V_{cR} and phase angle δ_{cR} of the voltage source representing the series converter are controlled between limits ($V_{cR\,min} \leq V_{cR} \leq V_{cR\,max}$) and ($0 \leq \delta_{cR} \leq 2\pi$), respectively.

The phase angle of the series-injected voltage determines the mode of power flow control.

If δ_{cR} is in phase with the nodal voltage angle θ_k, the UPFC regulates the terminal voltage. If δ_{cR} is in quadature with respect to θ_k, it controls active power flow, acting as a phase shifter. If δ_{cR} is in quadrature with the line current angle then it controls active power flow, acting as a variable series compensator. At any other value of δ_{cR}, the UPFC operates as a combination of voltage regulator, variable series compensator, and phase shifter. The magnitude of the series-injected voltage determines the amount of power flow to be controlled.

Based on the equivalent circuit shown in Figure (1b) and Equations (1), the active and reactive power equations are:
At bus k:

$$P_k = V_k^2 G_{kk} + V_k V_m [G_{km}\cos(\theta_k - \theta_m) + B_{km}\sin(\theta_k - \theta_m)] + V_k V_{cR}[G_{km}\cos(\theta_k - \delta_{cR}) + B_{km}\sin(\theta_k - \delta_{cR})] + V_k V_{vR}[G_{vR}\cos(\theta_k - \delta_{vR}) + B_{vR}\sin(\theta_k - \delta_{vR})] \quad \ldots (4)$$

$$Q_k = -V_k^2 B_{kk} + V_k V_m [G_{km}\sin(\theta_k - \theta_m) - B_{km}\cos(\theta_k - \theta_m)] + V_k V_{cR}[G_{km}\sin(\theta_k - \delta_{cR}) - B_{km}\cos(\theta_k - \delta_{cR})] + V_k V_{vR}[G_{vR}\sin(\theta_k - \delta_{vR}) + B_{vR}\cos(\theta_k - \delta_{vR})] \quad \ldots(5)$$

At bus m:

$$P_m = V_m^2 G_{mm} + V_m V_k [G_{mk}\cos(\theta_m - \theta_k) + B_{mk}\sin(\theta_m - \theta_k)] + V_m V_{cR}[G_{mm}\cos(\theta_m - \delta_{cR}) + B_{mm}\sin(\theta_m - \delta_{cR})] \quad \ldots (6)$$

$$Q_m = -V_m^2 B_{mm} + V_m V_k [G_{mk}\sin(\theta_m - \theta_k) - B_{mk}\cos(\theta_m - \theta_k)] + V_m V_{cR}[G_{mm}\sin(\theta_m - \delta_{cR}) - B_{mm}\cos(\theta_m - \delta_{cR})] \quad \ldots (7)$$

Series converter:

$$P_{cR} = V_{cR}^2 G_{mm} + V_{cR} V_k [G_{km}\cos(\delta_{cR} - \theta_k) + B_{km}\sin(\delta_{cR} - \theta_k)] + V_{cR} V_m [G_{mm}\cos(\delta_{cR} - \theta_m) + B_{mm}\sin(\delta_{cR} - \theta_m)] \quad \ldots (8)$$

$$Q_{cR} = -V_{cR}^2 B_{mm} + V_{cR} V_k [G_{km}\sin(\delta_{cR} - \theta_k) - B_{km}\cos(\delta_{cR} - \theta_k)] + V_{cR} V_m [G_{mm}\sin(\delta_{cR} - \theta_m) - B_{mm}\cos(\delta_{cR} - \theta_m)] \quad \ldots (9)$$

Shunt converter:

$$P_{vR} = -V_{vR}^2 G_{vR} + V_{vR} V_k [G_{vR}\cos(\delta_{vR} - \theta_k) + B_{vR}\sin(\delta_{vR} - \theta_k)] \quad \ldots (10)$$

$$Q_{vR} = V_{vR}^2 B_{vR} + V_{vR} V_k [G_{vR}\sin(\delta_{vR} - \theta_k) - B_{vR}\cos(\delta_{vR} - \theta_k)] \quad \ldots (11)$$

The UPFC converters are assumed loss-less converter valves in this voltage sources model, This implies that there is no absorption or generation of active power by the two converters for its losses and the active power demanded by the series converter at its output is supplied from the AC Power system by the shunt converters via the common D.C link. The DC link capacitor voltage V_{dc} remains constant. Hence the active power supplied to the shunt converter, P_{vR} equals the active power demanded by the series converter, P_{cR} .Then the following equality constraint has to be guaranteed,

$$\Delta P_{bb} = P_{vR} + P_{cR} = 0 \quad \ldots (12)$$

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,

$$P_{vR} + P_{cR} = P_k + P_m = 0. \qquad \ldots (13)$$

The UPFC power equations, in linearised form, are combined with those of the AC network.

For the case when the UPFC controls the following parameters: (1) voltage magnitude at the shunt converter terminal (bus k), (2) active power flow from bus m to bus k, and (3) reactive power injected at bus m, and taking bus m to be a PQ bus [7].

Implementation of UPFC in Newton Raphson Power Flow Algorithm

The algorithm for solving a power flow problem embedded with UPFC is implemented by using the MATLAB programming; the flow chart for this algorithm is shown in Figure (2).

The input system data includes the basic system data needed for conventional power flow calculation consisting of the number and types of buses, transmission line data, generation and load data, location of UPFC and the control variables of UPFC i.e the magnitude and angles of voltage output V_{cR} and V_{vR} of two converters. The inclusion of the UPFC increases one bus in the system. The UPFC power equations are combined with the network equations to give equation (14):

$$P_i + jQ_i = \sum_{j=1}^{n} V_i V_j Y_{ij} \angle\left(\theta_{ij} - \delta_i + \delta_j\right) + P_i' + jQ_i' \ldots (14)$$

Eq. (14) is linearised with respect to the variables of the network and the UPFC. The power flow constraint of the UPFC is included in the jacobian. The inclusion of these variables increases the dimension of the jacobian. The power equations are mismatched until convergence is achieved. A scalar multiplier is used to control the updating of variables to ensure that they converge in an optimal way to the solution point [8].

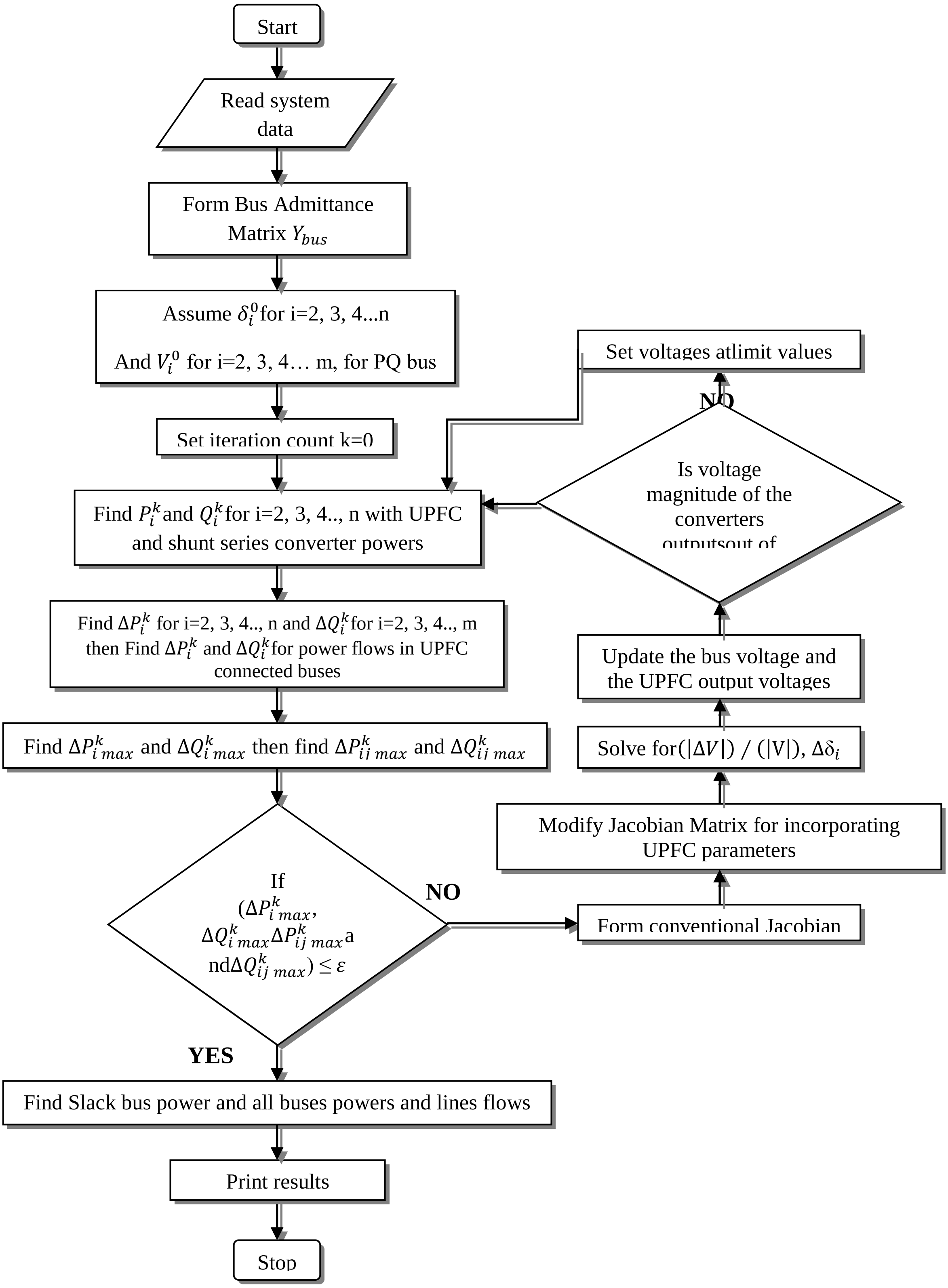


Figure (2) Flow Chart for load flow by N-R with UPFC.

GENETIC ALGORITHM

The GA is a search procedure that can be used to constrained problems; the constraints can be concerned with the fitness function. In that algorithm, issues for optimization concerning the UPFC equations that should be executed on the fitness function and all equality and inequality constraints. As shown in the flowchart the structure of the GA execution can be separated into the following three constituent: initial population generation, fitness evaluation and genetic operations.

In the genetic algorithm, the individuals are coded to chromosomes that contain variables of the problem. The configuration of chromosomes to reach the optimal installation of the UPFC has two categories of parameters; those are UPFC location and parameters setting (*VcR and VvR*) as coherent model parameters for UPFC.

- The first group of chromosomes inside the individual points to the positions locations of UPFCs hardware in the power system. This group defines in which transmission line the UPFCs should be structured.
- The second group (which starts from the first set end) describes the value of $V_{cR}$of series SVS. The limits for that set are randomly determined according to the working range from 0 to 1.
- At last, the third set (which starts form the second set end) describes the value of$V_{vR}$of shunt SVS. The limits for this set are randomly determined according to the range from 0 to 1.

The installation of UPFC will be in the optimal locations and with optimal setting of parameters, which will be achieved according to the following procedure:

1) Create randomly an initial population of open switches positions for the distribution system.
2) Evaluate each distribution system topology (chromosome) by running the load flow program. The fitness of an individual is determined by the active power loss.
3) Select parents' forms from the population for reproduction based on their fitness.
4) Apply search operator (crossover, mutation) to parents and generate offspring, which form the next generation.
5) Go to step 2, if some criterion is not reached [9].

From the flowchart given in Figure (3), higher values of **α** is for more directing the cursor on selecting only the well individuals. The best individual in the population is thus selected with the probability $\frac{\alpha}{\|P\|}$; the worst individual is selected with the probability$\frac{2-\alpha}{\|P\|}$. That procedure keeps the best individual in the new next generation [2].

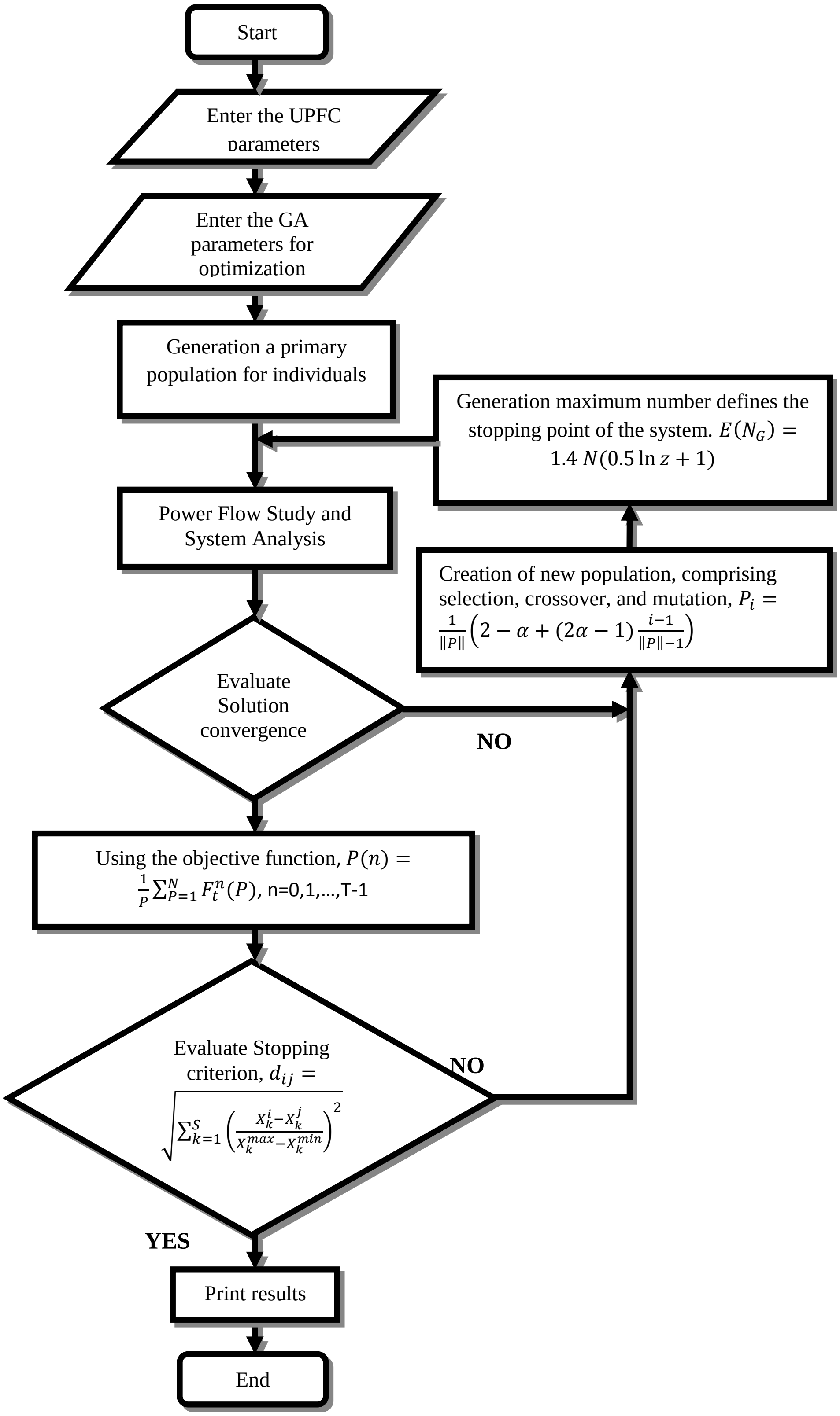


Figure (3) Flowchart of optimization procedure for GA.

SIMULATION AND RESULTS

In this work, it is assumed that a three phase to ground fault occurs at the lines near from the bus bar with a small fault impedance (Z_f = j0.001) as the worst situation for the Iraqi (400 KV)National Grid System, the voltage magnitude should not be dropped below 0.9 per unit (the permissible reduction in voltage is 10% at the high voltage and extra high voltage networks) with simulation ending time = 10 sec. The simulated results are discussed for the following cases:

Case1. Permanent Fault

- The system is in a pre-fault steady state.
- A fault occurs at t = t_f sec.
- The fault is removed by opening the breakers of the faulted line at t = t_c sec.
- The system is in a post-fault state.

Case2. Temporary Fault

- The system is in a pre-fault steady state.
- A fault occurs at t = $t_f$sec.
- The fault is removed by opening the breakers of the faulted line at t = t_c sec.
- The transmission lines are restored by closing the breakers of the faulted line at t = t_r sec.
- The system is in a post-fault state.

The transmission level in the Iraqi electrical network consists of 400 kV network, and the 132 kV network is connected to it. This work is limited to the 400 kV network with its buses and transmission lines.The network under consideration consists of 24 buses and 39 transmission lines; with total length of 3750 Km. Figure (4) shows the one line diagram of this network. The loads are represented by a static admittance and the lines by the nominal π sections. All network data are expressed in per-unit referred to a common base power of 100 MVA and common base voltage of 400 KV.

The Iraqi grid (400 KV) has 24 buses, 11 generation buses and 19 load buses. In the load flow solution, Musayab station (MUSP) is selected as a slack bus.The optimal locations for the UPFC devices specified by GA are depend on the total power losses and the voltage increased magnitude. GA results in Table (1) gives the optimal locations with the VSC's voltages depend on the highest negative pole position, that's because the more negative poles values the more the system becomes stable. Tables (2) (a) and (b) represent a comparison of the total power losses and eigen value analysis respectively of the system for each UPFC location, the shaded rows represent the selected lines for optimal locations of the UPFC depend on the minimum losses and maximum negative eigen values.

Table (1) GA results for Iraqi grid.

Line Number	Series VSC value (V_{cR})	Shunt VSC value (V_{vR})
3	0.2320	0.9867
11	0.2320	0.9867
13	0.2320	0.9867
20	0.2320	0.9867
36	0.2320	0.9867

Table (2a) Real power losses with and without UPFC.

		TOTAL GENERATION[p.u]		TOTAL LOAD[p.u]		TOTAL REAL LOSSES[p.u]
		REAL	**REACTIVE**	**REAL**	**REACTIVE**	
System without UPFC		58.481	21.9154	58	28.5138	0.48095
System with UPFC location on line number	1	58.481	21.9332	58	28.5138	0.48095
	2	58.4577	22.0453	58	28.5138	0.45774
	3	58.4657	21.9898	58	28.5138	0.46566
	4	58.4657	21.9898	58	28.5138	0.46566
	5	58.4579	22.0508	58	28.5138	0.45793
	6	58.4579	22.0508	58	28.5138	0.45793
	7	58.4808	21.9181	58	28.5138	0.4808
	8	58.4493	22.3226	58	28.5138	0.44932
	9	58.4797	22.4697	58	28.5138	0.47965
	10	58.4797	22.4697	58	28.5138	0.47965
	11	58.4133	22.429	58	28.5138	0.41333
	12	58.4627	22.1237	58	28.5138	0.46272
	13	58.4513	22.5577	58	28.5138	0.44129
	14	58.4546	22.4431	58	28.5138	0.45458
	15	58.4773	21.9217	58	28.5138	0.47731
	16	58.4773	21.9217	58	28.5138	0.47731
	17	58.4697	22.5743	58	28.5138	0.4697
	18	58.4775	22.2983	58	28.5138	0.47746
	19	58.456	22.0295	58	28.5138	0.45603
	20	58.4149	22.3283	58	28.5138	0.41489
	21	58.4268	22.3348	58	28.5138	0.42675
	22	58.4417	22.3498	58	28.5138	0.44165
	23	58.4806	22.0797	58	28.5138	0.48063
	24	58.4806	22.0797	58	28.5138	0.48063
	25	58.4645	22.2456	58	28.5138	0.46444
	26	58.4786	22.0289	58	28.5138	0.47855
	27	58.4808	22.0019	58	28.5138	0.48078
	28	58.4747	22.024	58	28.5138	0.47464
	29	58.4747	22.024	58	28.5138	0.47464
	30	58.4746	22.0397	58	28.5138	0.47458
	31	58.4767	22.3433	58	28.5138	0.47674
	32	58.478	21.936	58	28.5138	0.47797
	33	58.4803	21.9775	58	28.5138	0.48025
	34	58.4803	21.9775	58	28.5138	0.48025
	35	58.4796	22.0327	58	28.5138	0.47961
	36	58.4349	21.8401	58	28.5138	0.43492

	37	58.4751	22.5645	58	28.5138	0.4751
	38	58.467	22.2074	58	28.5138	0.46701
	39	58.467	22.2074	58	28.5138	0.46701

Table (2b) Eigen value analysis result.

		σ(max)	**Dynamic order**	**Pos. Eigen**	**Neg. Eigen**	**Complex Pair**	**Zero Eigen**
System without UPFC		-26.0239	99	0	98	28	1
System with UPFC location on line number	1	-26.0306	102	0	101	28	1
	2	-26.0032	102	0	101	29	1
	3	-26.0265	102	0	101	28	1
	4	-26.0265	102	0	101	28	1
	5	-26.0239	102	0	101	28	1
	6	-26.0239	102	0	101	28	1
	7	-26.0237	102	0	102	28	0
	8	-26.0239	102	0	101	28	1
	9	-26.0238	102	0	101	28	1
	10	-26.0238	102	0	101	28	1
	11	-26.024	102	0	101	29	1
	12	-26.0238	102	0	101	29	1
	13	-26.0237	102	0	101	27	1
	14	-26.0237	102	0	101	27	1
	15	-26.0228	102	0	101	29	1
	16	-26.0228	102	0	101	29	1
	17	-26.0233	102	0	101	28	1
	18	-26.0239	102	0	101	28	1
	19	-26.0026	102	0	101	30	1
	20	-26.0243	102	0	101	28	1
	21	-26.0243	102	0	101	28	1
	22	-25.9978	102	0	101	28	1
	23	-26.0228	102	0	101	28	1
	24	-26.0228	102	0	101	28	1
	25	-26.0239	102	0	101	28	1
	26	-26.0056	102	0	101	30	1
	27	-26.0048	102	0	101	29	1
	28	-25.8236	102	0	101	29	1
	29	-25.8236	102	0	101	29	1
	30	-25.8122	102	0	101	28	1
	31	-25.8242	102	0	101	28	1
	32	-26.0089	102	0	101	29	1
	33	-26.0047	102	0	101	29	1

	34	-26.0047	102	0	101	29	1
	35	-26.0118	102	0	101	30	1
	36	-25.9761	102	0	101	29	1
	37	-26.0223	102	0	101	28	1
	38	-25.4757	102	0	101	27	1
	39	-25.4757	102	0	101	27	1

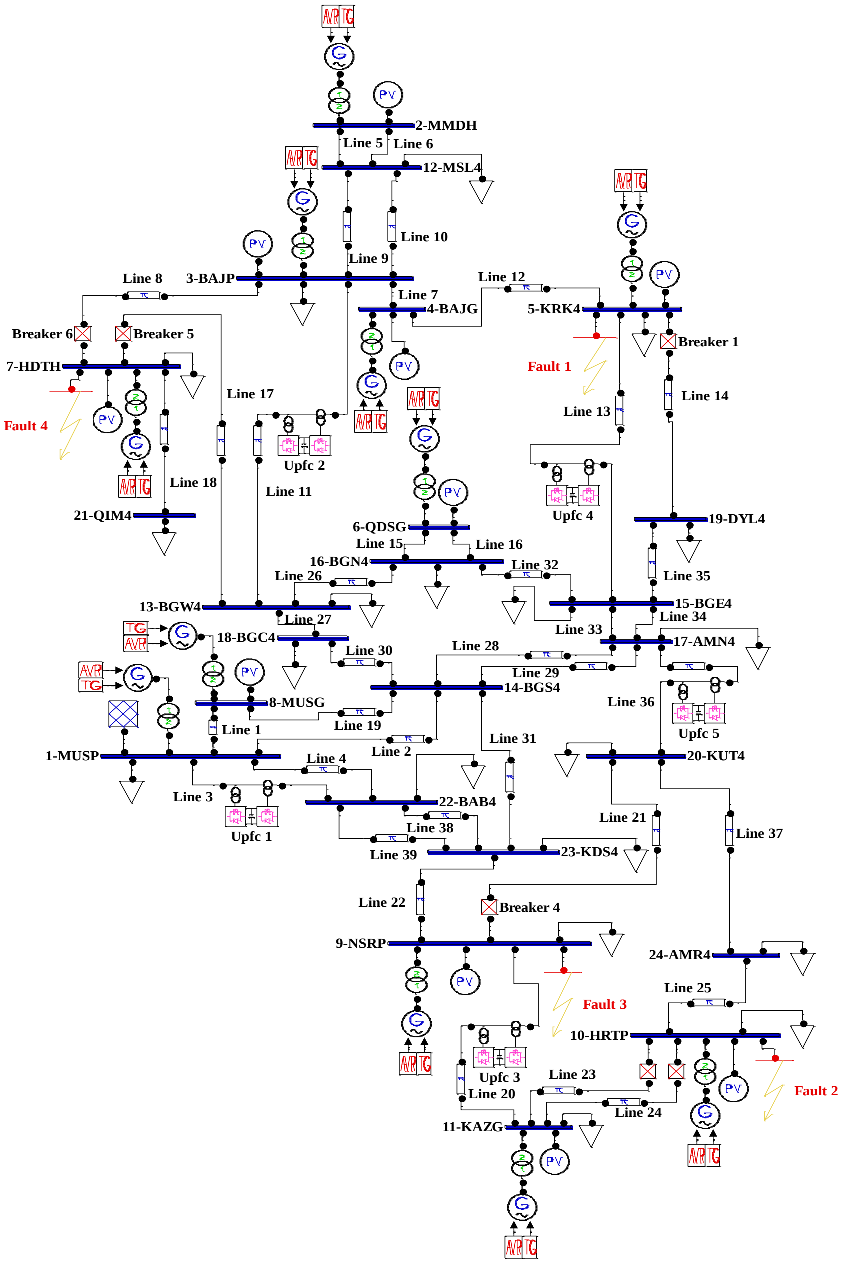


Figure (4) Iraqi (400kV) National Super Grid System (INSGS) [10].

After the optimal location of UPFC device has been selected the system stability is then tested by applying a three phase to ground fault near the bus bar at different location (bus KRK4, HRTP, NSRP and HDTH) in each fault the system test repeated for the two cases 1 and 2, For each case a comparison made between the system without and with UPFC devices depends on the fault duration according to the clearance time conditions.

Fault near bus KRK4

Fault at line 14 near KRK4 with breaker1 opened of line 14 near KRK4 bus without and with the UPFC devices.

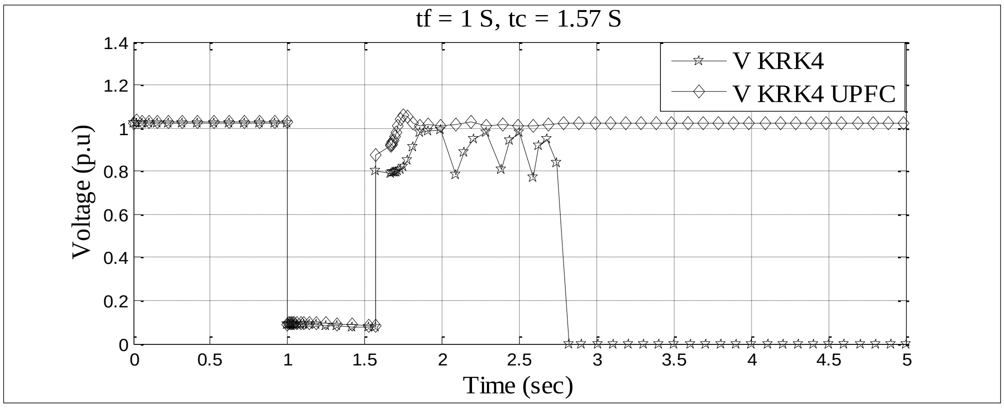


Figure (5a) Voltage of KRK4 Bus with and without UPFC.

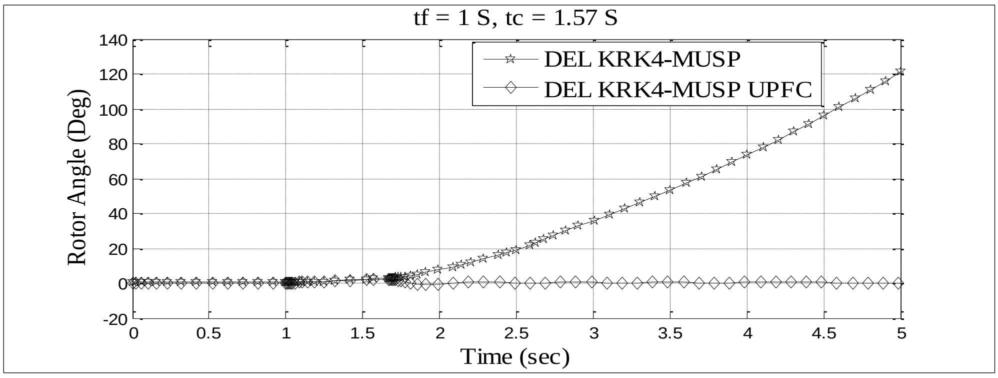


Figure (5b) Rotor angle of KRK4 Gen. with and without UPFC.

Fault near bus HRTP

Fault at lines 23 and 24, near HRTP bus with the breakers on lines 23 and 24, near HRTP bus are opened, with and without UPFC on lines (3, 11, 13, 20 and 36).

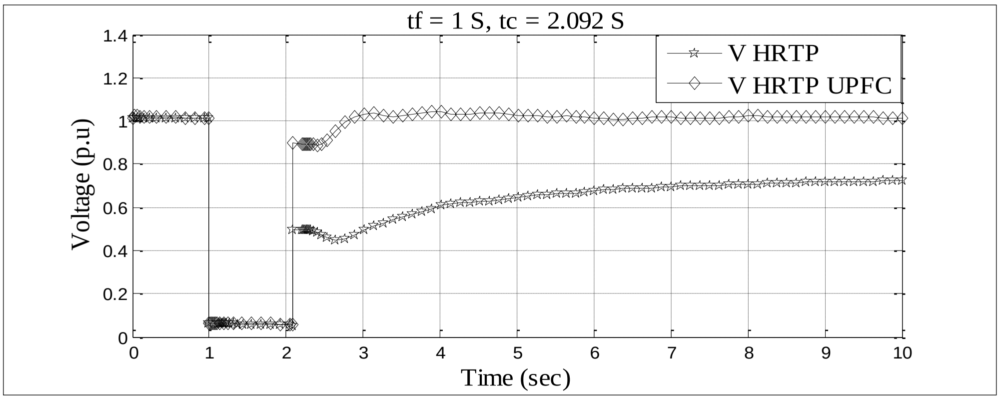


Figure (6a) Voltage of HRTP Bus with and without UPFC.

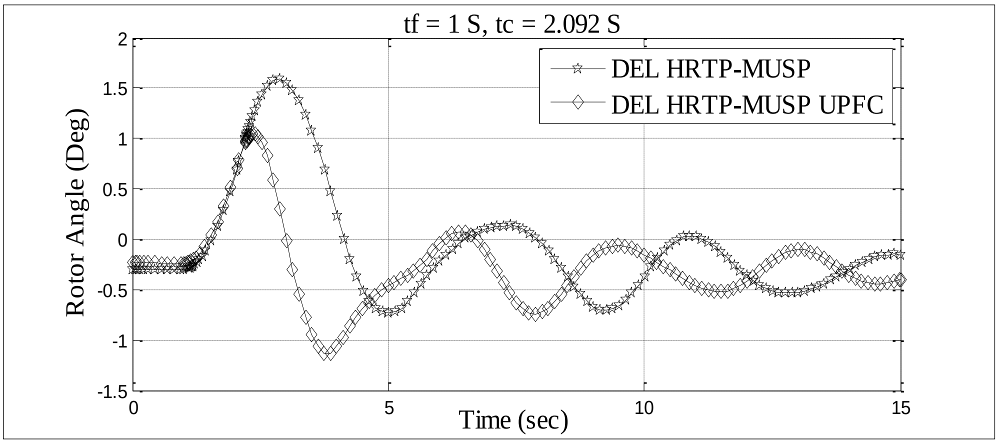


Figure (6b) Rotor angle of HRTP Gen. with and without UPFC.

Fault near bus NSRP

Fault near bus 9-NSRP with breaker on line 21, with and without UPFC;

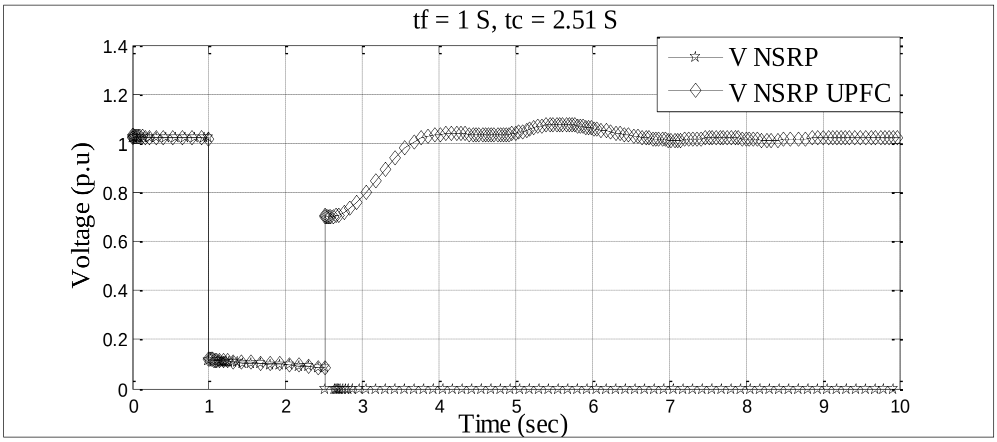


Figure (7a) Voltage of NSRP Bus with and without UPFC.

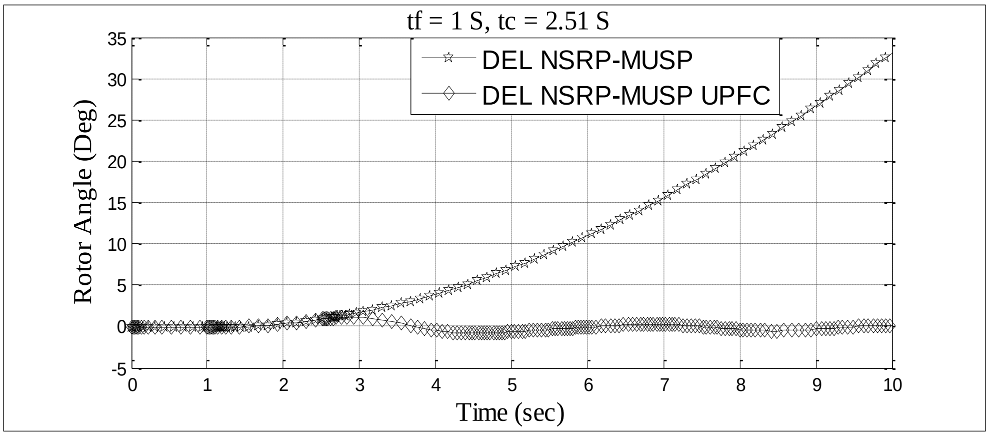


Figure (7b) Rotor angle of NSRP Gen. with and without UPFC.

Fault at bus HDTH

Fault on HDTH bus with disconnection of the circuit breaker on lines 8 and 18 which leads to outage of the HDTH generator bus and QIM4 load bus from the power grid, comparison made to the system between the two situations; with and without using UPFC devices.

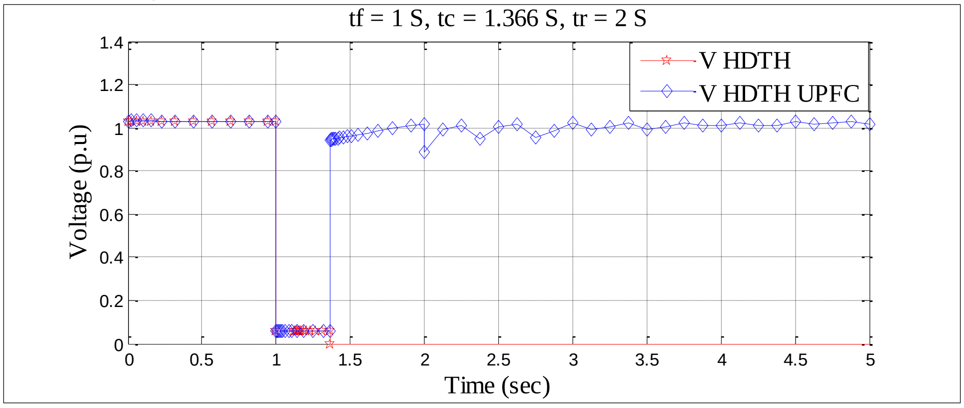


Figure (8a) Voltage of HDTH Bus with and without UPFC.

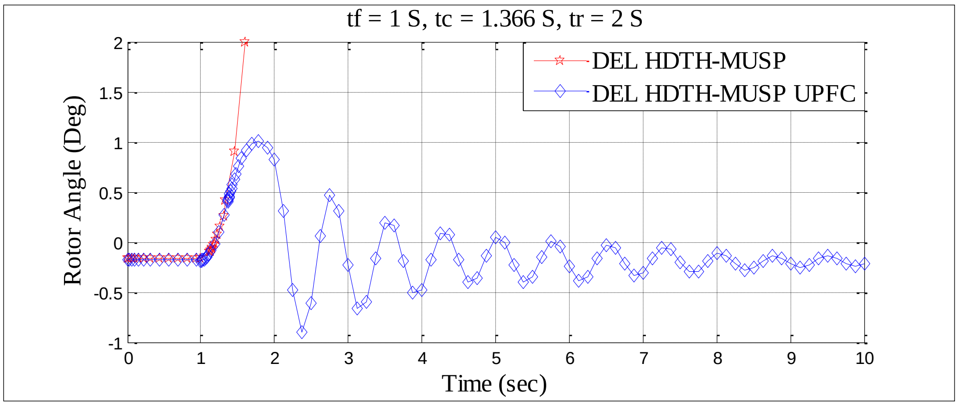


Figure (8b) Rotor angle of HDTH Gen. with and without UPFC.

CONCLUSIONS

The placement of FACTS device can’t be anywhere because in some locations it will be harmful to the system.Genetic Algorithm (GA) can be used to determine, the optimal location, and the optimal settings of the UPFC to enhance the performance of the power network especially for buses voltage and angles violations during faults and the contingency outage cases.Increasing the number of FACTS in the grid more than five devices in the Iraqi grid will be useless for the system.The simulation has been implemented using PSAT based on MATLAB programming language (Iraqi national grid) system shows the proposed UPFC has efficient and quite satisfactory results.Indices have been proposed to evaluate the performance and are used to determine the suitable location and parameter settings of the UPFC in the network.The optimal location of UPFC is specified for Iraqi National Grid System in lines 3, 11, 14, 20 and 36 depending on the total power losses and Eigen values analysis, these locations enhanced the stability performance of the network when fault occurs.The stability of system depends on the fault location and fault duration time.The study and analysis of the voltage stability with rotor angle is very important because some cases showed that the rotor angles takes more time than the voltage until it became unstable during fault conditions especially when UPFC devices are connected to the system.

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