Power system diagnostic condition monitoring of transformative intrinsic algorithm based unified power flow control in high voltage grid system analysis

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Abstract-Nowadays, Power system stability analysis is essential to ensure reliable and continuous service to consumers. The problem of the poorly damped low-frequency of the power systems oscillations has been an issue of concern to the power transmission system for a long time because they limit power transfers in transmission lines and induce stress are presented in the distributed generation. Due to this disturbances, power systems experience these poorly damped low-frequency oscillations. The dynamic stability of power systems is also affected by these low-frequency oscillations. Due to this constraints, the proper optimization designing will be required of these oscillations which can be well damped and hence the system stability is enhanced. This proposed work is analyzing the Distribution transmission consider which includes UPFC based low-frequency stabilization using Transformative Intrinsic Algorithm (TIA) is approached. The coordinated proposed controller is effectively optimizing the damping control parameters under different criteria. The projected modeling is applied in the Matlab 2017 environment for different test condition which is compared with the conventional method of regulating the damping control, settling time, sag voltage, parameters to show the advantages and robustness of the proposed design.

Keyword: Low-frequency oscillation, unified power flow controller, Transformative Intrinsic Algorithm (TIA).

1. Introduction

Recently with the development of Power electronics, different nonlinear loads like switched mode power supply, uninterruptible power supply; speed control drives, etc. are used tremendously. These loads introduce current harmonics in power lines. These current harmonics causes poor power factor of the line, overvoltages or current due to resonance and also affects the performance of the equipment operating simultaneously with the nonlinear load. To overcome this problem and to use renewable energy sources.
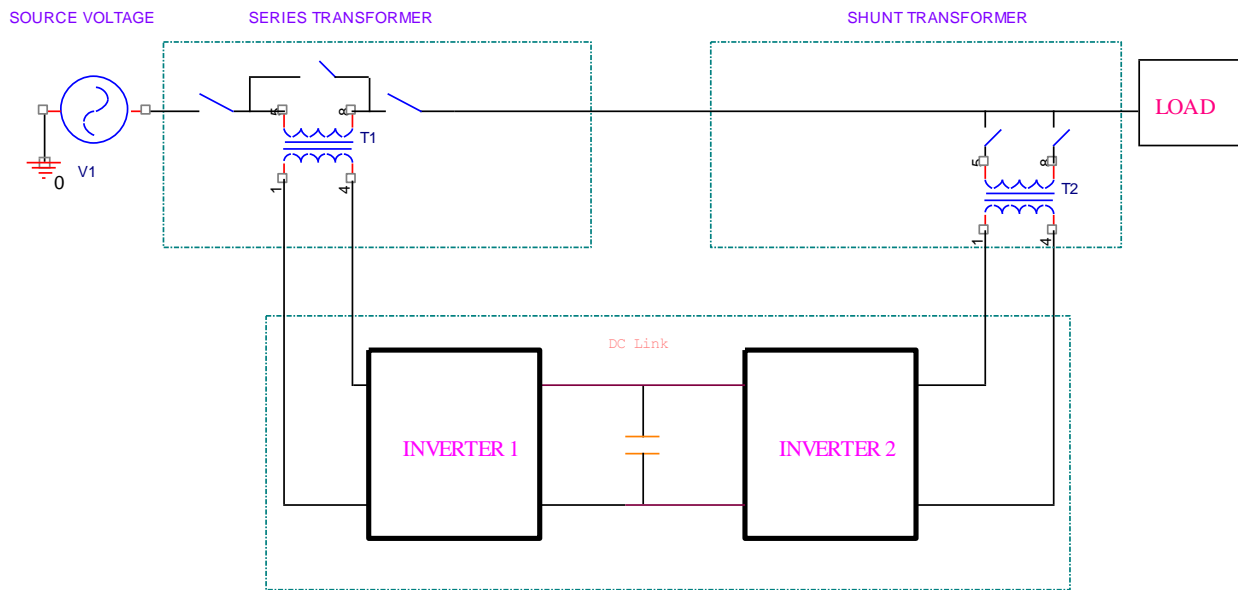
The installation of large non-linear electronic devices, as well as the sudden disturbing events, causes various power quality (PQ) problems. These PQ problems include voltage sag, harmonics, flicker, etc. and are responsible for distorting, the nature of supply voltage and the current waveform. Thus these PQ problems degrade the performance of sensitive loads like electric drives, computer systems, and industrial electronic controllers. It further impinges the economic loss to industrial customers. Voltage sag is the frequently occurring disturbance.

Sag is defined as a decrease between voltage and current at the power frequency for durations. So, reduction in supply voltage may cause tripping of sensitive loads using protection circuits and can stall the industrial processes. This problem can be resolved if the load does not experience these disturbances in the power system. Voltage sags can occur at the starting of massive three-phase loads like an induction motor, due to some unsymmetrical fault like line-to-ground fault, sudden switching of capacitor banks, transformer charging, switching in or out of single-phase load. To mitigate PQ problems, power electronics technology along with control strategies is embedded which is commonly named as

Custom Power Device (CPD). CPD includes shunt compensation devices, series compensation devices as well as a combination of shunt and series compensation devices.

Presently, it is well established in the scientific community that the UPFC can increase the power flow capacity and improve the stability of an electric power transmission system through the proper design of its controller. Over the past several decades, linear and nonlinear control techniques have been successfully proposed and applied in the literature for the control of UPFC based on modern and classical control theories. Thus, only partial and quite weak results have been obtained regarding online implementation feasibility. However, the complexities associated with the adaption of membership functions and computation requirements for control techniques here the Transformative Intrinsic Algorithm (TIA) is proposed to optimize the power flow in the Transmission system. A radial basis function neural network has been designed to control the operation of the UPFC to improve its dynamic performance.

SOURCE VOLTAGE　　　　SERIES TRANSFORMER　　　　　　　　　　　　SHUNT TRANSFORMER

LOAD

V1

0

T1

T2

DC Link

INVERTER 1

INVERTER 2

UPFC CONTROLLERS

Figure 1. UPFC Configuration system

The Proposed TIA operates UPFC not only for sag correction but for mitigation of the zero-sequence component if present in the network. Thus, a balanced critical load can be operated under symmetrical phase conditions. To analyze the effectiveness of the proposed algorithm, the MATLAB/Simulink environment is utilized. The analysis of the compensation characteristics of different (high power filters) HPF configurations is carried out. The design of the control method is based on both the schemes of the hybrid filter, different control strategy and power circuit design are considered. The primary current and distribution system harmonic currents are independently controlled by a current detecting scheme. The elimination of the harmonic current is performed by using hybrid power filters. A flexible and versatile solution to voltage quality problems is offered by active power filters. The proposed technique, based on conventionally power quality improvement was done through shunt filter and series filter compensation and other PQ problems. A major part of the hybrid filter reducing voltage and current harmonics at a reasonable cost.

2.　　Literature review

The investigation of UPFC is mainly focused on the improved topologies, its function of power flow regulation and fault performance. In a structure is proposed to eliminate the cumbersome transformer [1]. A transient energy function based

model predictive control method for UPFC is developed to reduce control cost and enhance power grid resilience. However, it has the stability problem, and the system may diverge if encountered with some contingency scenarios [2]. The UPFC controls, simultaneously or

Selectively, all parameters which effect on power flow in the transmission line, i.e., voltage amplitude and phase angle and series impedance of transmission line [3]. The main function of the current converter is to provide active power to the current converter through the DC side, and the corresponding active power is supplied by active power side using the coupling transformer [4]. The UPFC can control simultaneously or selectively system parameters and has been recognized as a most powerful device available in the control of large transmission systems [5].

By the theoretical research of UPFC, experimental research also has fundamental significance and value, and quite a lot of scholars have started the research work. According to the UPFC system based on MMC, the establishment of the mathematical model is studied and simulates the dynamic characteristics of MMC [6]. Steady-state models of UPFC described in the literature employ the power balance equation, resulting in the equality of the series and shunt active power of converters assuring no internal active power consumption or generation [7]. The injected series voltage from Inverter-2 can be at any angle concerning the line current, which provides complete flexibility and controllability to control both active and reactive power flows over the transmission line [8]. The unified power flow controller (UPFC) can control, simultaneously or selectively, all the parameters affecting power flow in the transmission line [9]. FACTS devices improve the efficiency of the existing network by re-dispatching the line flow in such a way that the violating thermal limit is not exceeded [10]. The presence of FACTS controllers such as UPFC in the transmission system and wind-farm integration to the grid through transmission lines (off-shore wind integration) poses different challenges to the existing relaying schemes [11]. Unified power flow controller (UPFC) to improve the stability margin and also to damp out the power

fluctuations in a combined wind and wave energy production system connected to the bulk power network [12]. To improve the performance of distance protection in the presence of UPFC, the series voltage and reactive current injected by UPFC, to predict the adaptive trip boundary of distance relay based on generalized regression neural network [13].

The trial neighborhood solution vectors are generated by perturbing the initial solution vector based on the uniform probability distribution function. Also, the upper limits of UPFC parameters are used to limit the ranges of perturbation [14]. A distance relay performance in a compensated line with UPFC for different fault conditions. In the impact of series and shunt compensating parts of a UPFC on the distance relay is analyzed individually and collectively [15]. The UPFC consists of a shunt VSC and a series VSC connected via a universal dc bus which includes a dc capacitor for ripple control [16]. The UPFC shunt converter is used to regulate the dc-link voltage, whereas the series converter is used to control the power flow to achieve line loss minimum condition [17]. The capabilities of controlling power flow in the transmission line, improving the transient stability, mitigating system oscillation, and providing voltage support [18]. A new control technique for UPFC to regulate load voltage to be equal in magnitude to source voltage underline loss minimization [19]. The conventional UPFC has been put into several practical applications, which requires an interface transformer to isolate each inverter from the transmission line [20].

3. Materials and methods

Numerous increasing demand for electrical power for different types of the load is degrading the quality of power in the system. So, to improve the power quality, different Flexible AC transmission system (FACTS) devices are used to maintain controllability and capability of the electrical power system.One of the numerous arrangements is the utilization of a jointed mechanism of the shunt and active arrangement channels like unified power flow conditioner (UPFC). This device consolidates a functioning shunt and series channel with an arrangement dynamic channel in setup, to all the

while repay the supply voltage and the heap current or to moderate any voltage and current changes and power calculate amendment a power dispersion organize. Hence, it is robust and produces an optimal response in the presence of system parameter uncertainty and disturbances. The performance of UPFC with Transformative Intrinsic Algorithm (TIA) is improved transmission system. This work also covers the variation of real power with variation in the angle of injected voltage. The effect of variation of reactive power with the variation in the magnitude of voltage is studied. The coordinated proposed controller is effectively optimizing the damping control parameters under different criteria. Also, system stability will improve with the coordinated control design. The optimized power will be synchronous with the network system.
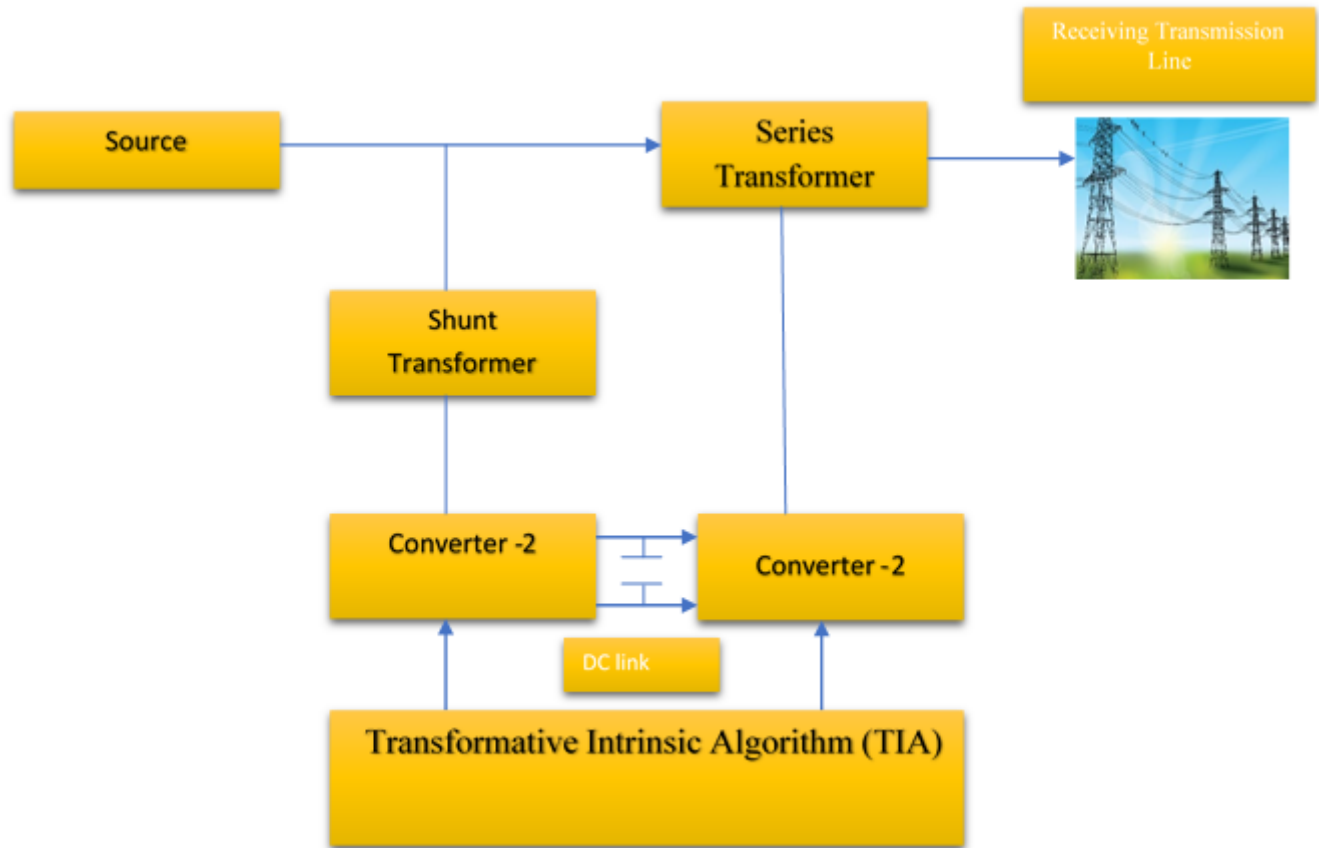

Figure 2. proposed block diagram for UPFC controller

Figure 2 shows the proposed block diagram of the unified power flow control which is mainly optimizing the transmission line sag voltage and stabilize the frequency oscillation. Since the diagram, it consists of reactive power compensation of series transformer and shunt transformer with the proposed Transformative Intrinsic Algorithm (TIA) strategy for optimizing the power transmission reliability and stability. The general structure of proposed TIA based UPQC includes two inverters, and it is related to an inclination voltage generator as presented in this model.

3.1. Transformative Intrinsic Algorithm (TIA) Strategy to Enhance the Power Quality in Transmission Line

These works introduce the Transformative intrinsic algorithm to optimize the non-linear constraint in the transmission line. This technique used is to reduce power transmission loss, Frequency oscillation, and improve the magnitude of the voltage. The UPFC system can be used for the static and dynamic compensation of the ac transmission line. Transformative intrinsic algorithm control algorithm

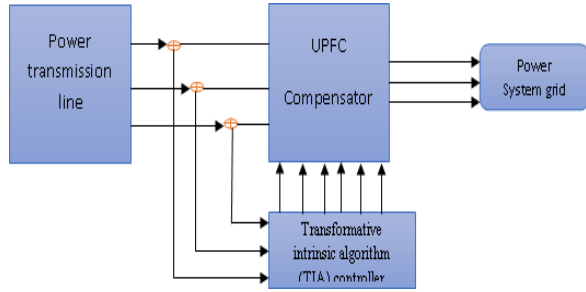provides a practical solution for the power quality stabilization.

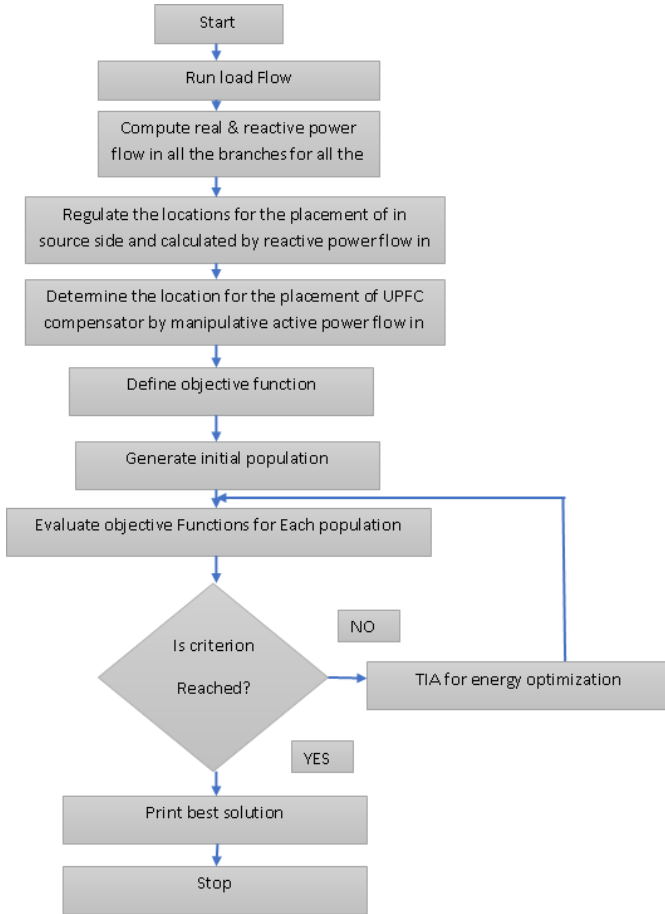**Figure 3. UPFC based Transformative intrinsic algorithm for energy optimization**

Figure 4. Flowchart for the proposed system

From Figure 3 it shows the unified power flow controller (UPFC) based Transformative intrinsic algorithm for power quality optimization in the transmission line is presented. The control system describes the assume the series and shunt converters are as the ideal controller's voltage sources, where the on-line transmission values of the fundamental components values are analyzed and optimized by the proposed algorithm.

Figure 4 shows the proposed optimizing procedures for the transformative intrinsic algorithm which is effectively optimized by the UPFC controller.

3.1.2. Transformative Intrinsic algorithm steps

Input: Compute real & reactive power flow in all the branches, the location of UPFC, Damping oscillation.

Outputs: optimized VSC and Real power loss

Step 1: Compute the system data such as load bus voltage values, source voltage, sag, and swell voltages and all other values.

Step 2: Initialize the value in the present system and constants of the Transformative intrinsic algorithm

Step 3: Identify the sag voltage in the transmission line and optimized by the unified power flow controller (UPFC) using the Transformative intrinsic algorithm.

Step 4: Generate randomly 'n' number of voltage variation in grid lines. Where find out the $(-V_{imax})$ and $(+v_{imax})$.Each representing as rating sag voltage in the system.

Step 5: To place the all n number of voltage variation in UPFC of the respective candidate locations and load flow analysis of total real power loss (P_L).

Step 6: The number of particles to find the real power losses and corresponding to each particle is evaluated using the equation for maximum loss reduction.

$$FV = P_{L,normal} - P_{L,UPFC.} \qquad (1)$$

Step 7: The obtained fitness values and the best value among all the P_{best} values are identified.

Step 8: The difference between the maximum fitness and average fitness value is called the error.

Error = (maximum fitness - average fitness)… (2)

Step 9: Determine the r_{ij} values of the following equation

$$r_{ij} = G_{best}FV - P_{best}FV\ldots$$
(3)

r_{ij} Is obtained by optimizing the difference between the best fitness value $G_{best}FV$ and $P_{best}FV$

$$GbestFV = \frac{V1V2\sin\delta}{X}.$$
(4)

Where,

P=active power transmitted

V1=Line to line voltage of source V1

V2=Line to line voltage V2

X=Reactance of interactions

$$\beta = Angle\ of\ V1\ concerning\ v2$$

$$P = \frac{V1V2\sin(\delta+\Psi)}{X+X_{PST}}$$
(5)

Where,

$$X_{PST} = PST\ leakage\ reactance$$

Ψ=PST phase shift

= angle of T2 voltage with respect to T1

Step 10: New fitness values are calculated for the new positions of all the fireflies. If the new fitness value is better than previous P_{best} value, then the P_{best} value for that Transformative intrinsic algorithm is set to present value. Similarly G_{best} Value is identified from the latest P_{best} values.

Step 11: The iteration count is incremented and if the iteration count is not reached a maximum then go to step 3.

3.2. Hybrid filters

Hybrid filter are high improve the power quality problem in both transmission and load side. The shunt and series filters are optimized optimal power flow in the harmonics reduction in the proposed system.
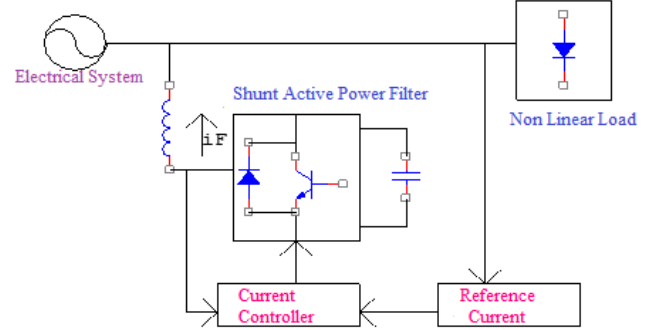
3.2.1. Shunt filter

Figure 5. Circuit diagram of shunt filter

In a transmission line shunt, APF (active power filter) is usually connected in parallel. Shunt APF is used to optimize for voltage distortions & harmonics which are presented due to current variation. Due to differential load, there are harmonics in load current, so to keep source current completely sinusoidal and distortion free we use Shunt filter.

The purpose of the active shunt filter is to inject instantaneous active power p_{AF2} into the supply and to keep instantaneous reactive power q_{AF2} to be zero. Here, p_{AF2} is equal to p_{AF1}, so that no variation occurs in the dc link voltage. Accordingly, p_{AF2} and q_{AF2} are given by,

$$\begin{bmatrix} p_{AF2} \\ q_{AF2} \end{bmatrix} = \begin{bmatrix} p_{AF1} \\ 0 \end{bmatrix}$$
(6)

The instantaneous active power drawn from the supply, p_S equals p_L because p_{AF2} and p_{AF1} cancel each other at the receiving terminated. Here, p_S and q_s are given by

$$\begin{bmatrix} p_S \\ q_s \end{bmatrix} = \begin{bmatrix} p_L \\ q_L + q_F + q_{AF1} \end{bmatrix}$$
(7)

$$= \begin{bmatrix} 3V_{sf}I_L\cos\emptyset \\ 3(V_{sf} + \Delta v_s)(I_L\sin\emptyset + I_F) \end{bmatrix}$$
(8)

Although voltage flicker Δv_s. Is superimposed on the supply voltage v_s., p_S is constant, while q_s is not constant because q_{AF1} fluctuates.

Shunt APF was injecting compensating current so that the input current is entirely sinusoidal and free from distortions. Figure 5 shows the Controlling of Shunt APF is done by hysteresis band PWM techniques. In hysteresis band, PWM techniques output current follows the reference and current and is within the fixed hysteresis band. In recent years of development, the requirement of harmonic and reactive power has developed, causing power quality problems.
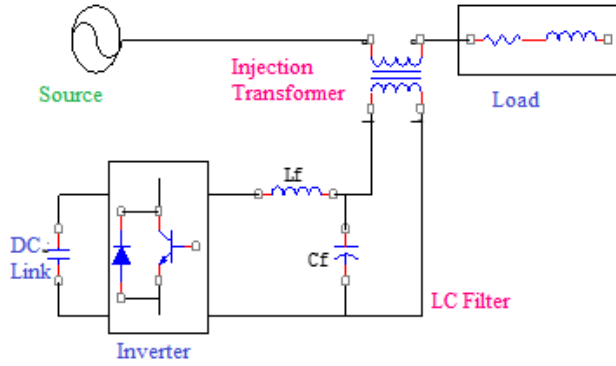
3.2.2. Series filter

Figure 6. Circuit diagram of series filter

The required voltage which is generated by series (Active power filter) APF so that the voltage at load side is entirely balanced and regulated Sinusoidal signal is injected into the grid line with the help of these series transformers. The series transformer turns ratio should be appropriate so that injecting voltage is suitable such that it injects an optimizing voltage which will entirely make the load side voltage balanced, and also it minimizes the current flowing through series inverter shows in Figure 6.

Three-phase balanced voltages, $V_1, V_2,$ and V_3, are given by

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \sqrt{2}V_{Sf} \begin{bmatrix} coswt \\ \cos\left(wt - \frac{2\pi}{3}\right) \\ \cos\left(wt + \frac{2\pi}{3}\right) \end{bmatrix} \quad (9)$$

Where,

V_{Sf}: Voltage amplitude

W: supply angular frequency.

Because voltage flicker is considered a low-frequency amplitude modulation of the fundamental supply voltage, voltage flicker ΔV_S in each phase is given as

$$\begin{bmatrix} \Delta V_1 \\ \Delta V_2 \\ \Delta V_3 \end{bmatrix} = \sqrt{2}\Delta V_S \begin{bmatrix} coswt \\ \cos\left(wt - \frac{2\pi}{3}\right) \\ \cos\left(wt + \frac{2\pi}{3}\right) \end{bmatrix}$$

$$(10)$$

Where,

$\Delta V_S = \Delta u \cos(wt)$

Δu: Amplitude of voltage flicker,

W: angular frequency of voltage flicker.

Because ΔV_S is canceled by the active series filter, the load terminal voltage, equals ΔV_S, So that no voltage flicker appears at the load terminal. Therefore, the load current has a constant amplitude, and the passive filter current has a constant amplitude. With the active series filter operating, the passive filter is assumed to absorb all the load current harmonics.

A transformer is an electrical device that varying electrical energy between the two or more coils through electromagnetic induction mainly without change frequency. A modified current in one coil of the transformer induced a varying electromagnetic field, which in modifying it turns induces a voltage in a second coil. Power can be transmitted between the two coils through the magnetic field, without a metallic connection between the two circuits. Induction discovered in described this effect. Transformers are used to step up or step down the alternating voltages in electric power applications.

3.2.3. Inverter switching characteristics

The generation of reference quantities and realizing them through VSIs are the two critical aspects in the realization of any active power filter. In this section, the control algorithm for reference generation and switching control technique are presented. A primary three-phase inverter consists of three legs; each leg has two power switches. The basic principle of Transformative Intrinsic Algorithm is based on the eight possible switching combinations of the VSI switches.

Table 1. Inverter Switching

Sector	Switches (S1, S3, S5)	Switches (S4, S6, S2)
1	S1 = Ta + Tb + To/2 S3 = Tb + To/2 S5 = To/2	S4 = To/2 S6 = Ta + To/2 S2 = Ta + Tb + To/2
2	S1 = Ta + To/2 S3 = Ta + Tb + To/2 S5 = To/2	S4 = Tb + To/2 S6 = To/2 S2 = Ta + Tb + To/2
3	S1 = To/2 S3 = Ta + Tb + To/2 S5 = Tb + To/2	S4 = Ta + Tb + To/2 S6 = To/2 S2 = Ta + To/2
4	S1 = To/2 S3 = Ta + To/2 S5 = Ta + Tb + To/2	S4 = Ta + Tb + To/2 S6 = Tb + To/2 S2 = To/2
5	S1 = Tb + To/2 S3 = To/2 S5 = Ta + Tb + To/2	S4 = Ta + To/2 S6 = Ta + Tb + To/2 S2 = To/2
6	S1 = Ta + Tb + To/2 S3 = To/2 S5 = Ta + To/2	S4 = To/2 S6 = Ta + Tb + To/2 S2 = Tb + To/2

3.3. Unified power flow controller for power

The Fundamentally UPFC (Unified Power Quality conditioner) is an equipment which is used for compensating for voltage distortion and voltage unbalance in a power system so that the voltage at load side is completely balanced and sinusoidal and perfectly regulated, and also it is used to compensate for load current harmonics so that the current at the source side is perfectly sinusoidal and free from distortions and harmonics. UPFC is a combination of a Shunt Active power filter and Series Active power filter. Here Shunt Active power filter (APF) is used to compensate for load current harmonics and make the source current completely sinusoidal and free from harmonics and distortions. Shunt APF is connected parallel to the transmission line. Here Series APF is used to mitigate for voltage distortions and unbalance which is present in supply side and make the voltage at load side perfectly balanced, regulated and sinusoidal.

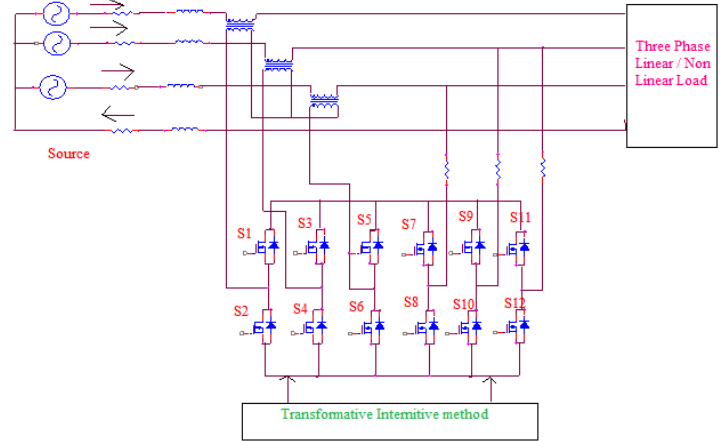The series transformer is connected in series with the transmission line flow improvement

Figure 7. Circuit diagram of a unified power Flow controller for power flow improvement

. UPFC consists of two voltage source inverters connected back to back through a DC link capacitor in a single phase, three phase-three wire, and three phase-four wire configuration shown in **figure 7**. The voltage of phase "a" can be expressed as

$$u_{sa}(t) = u_{1pa}(t) + u_{1na}(t) + \sum_{k=2}^{\infty} u_{ka}(t) \tag{11}$$

$$= U_{1p}\sin(\omega t + \theta_{1p}) + U_{1n}\sin(\omega t + \theta_{1n}) +$$

$$\sum_{k=2}^{\infty} U_{ka}\sin(k\omega t + \theta_{ka}) \tag{12}$$

Where u_{1pa} is the fundamental frequency positive sequence component while is the negative sequence component. U_{1p} and U_{1n} are the positive, negative sequence voltages amplitudes respectively θ is the initial phase of voltage. The last term of the above equation represents the harmonics in the voltage.

The inverter in shunt APF is controlled as a variable current source inverter, and in series, APF is controlled as a variable voltage source inverter. Earlier passive filters where also used for compensation of harmonics and voltage distortion but due to their many disadvantages they are not used nowadays. Unified power quality conditioners (UPFCs) allow the mitigation of voltage and current

disturbances that could affect sensitive electrical loads while compensating the reactive load power.

4. Results and discussion

4.1. Overall MATLAB Simulation

The proposed Transformative Intrinsic Algorithm based UPQC was developed by using Mat lab Simulink software, and the simulation model was shown in following **figure 8.** In this simulation, a Transformative intrinsic algorithm controller will be needed to balance the power and maintain the direct voltage constant; especially when the system is running under various conditions. The experimental results of the improved algorithm are compared with the methods. Matlab 2017a is the most common manipulation and operating software. According to the specific operation and innovative condition for implementing the algorithm for progression belongs to the respective methods to view and analyze simulation result in image processing.
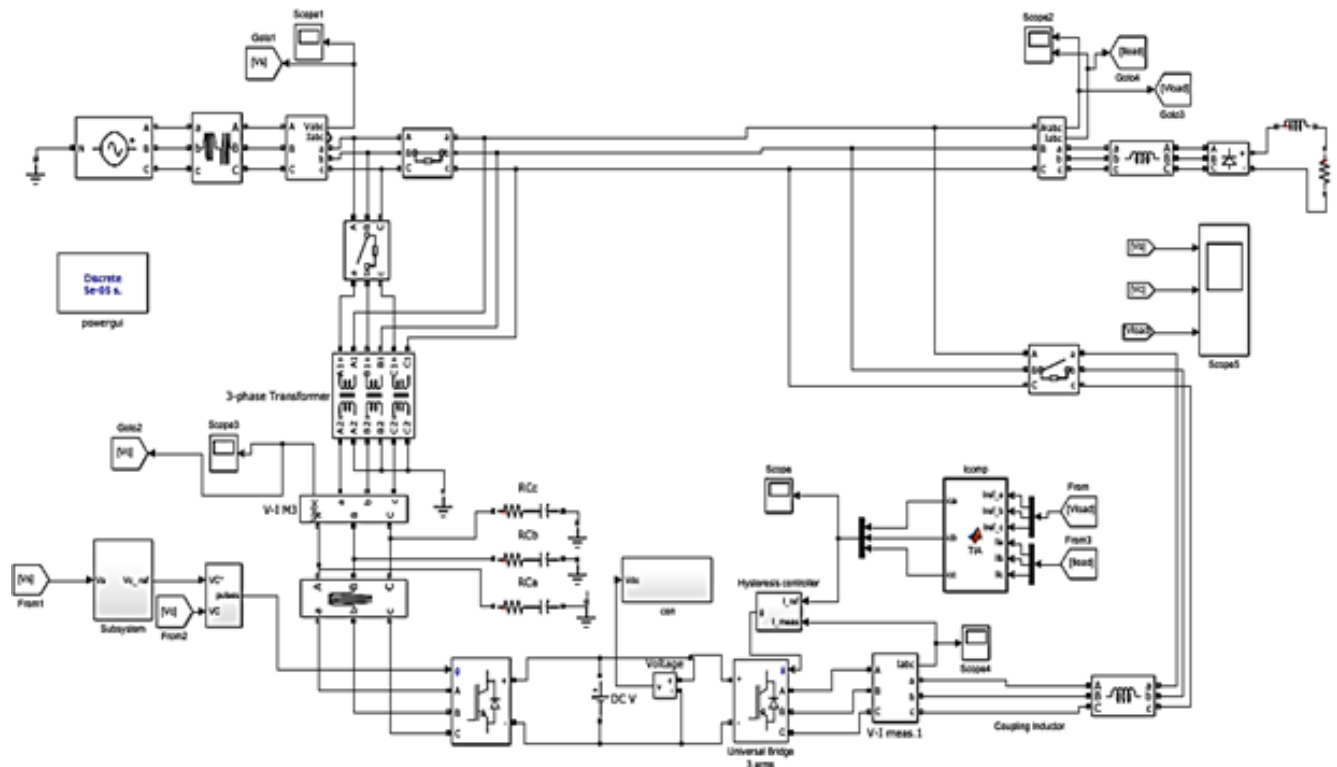
Figure 8. Simulink Model of Proposed system

The above **figure 8** shows the simulation model of the proposed Transformative Intrinsic Algorithm based Unified power flow conditioner. Figure 9 shows the system Source voltage, and the voltage oscillates, and the harmonics are high in this system and also voltage sag is present with a Damped waveform.
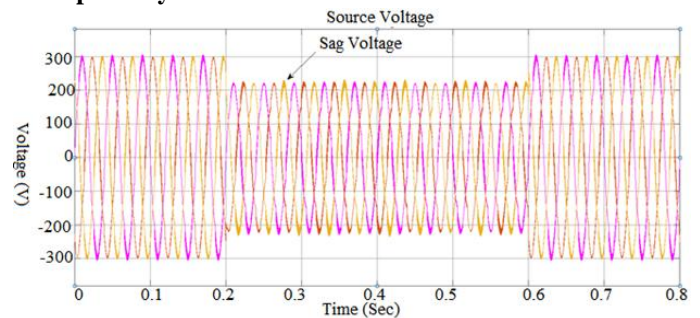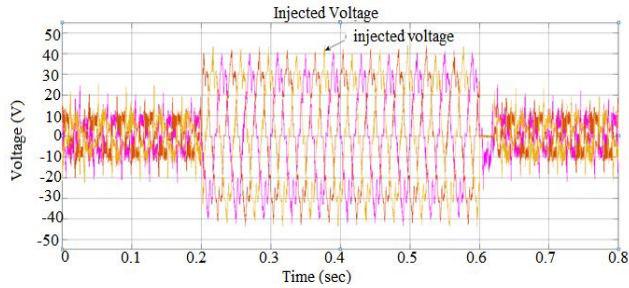
Figure 10. Simulated waveforms of Injected Voltage for proposed UPFC model

Figure 10 shows the system Injected voltage, which will improve the sag voltage which is present in the source side waveform.
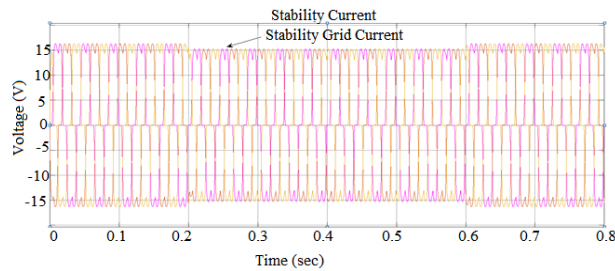

Figure 11. Simulated waveforms of Grid current for proposed UPFC model

Figure 11 shows the stability grid current condition is analyzed to confirm the performance of the UPQC under the proposed Transformative Intrinsic Algorithm based UPQC, and the harmonics are low in this system.
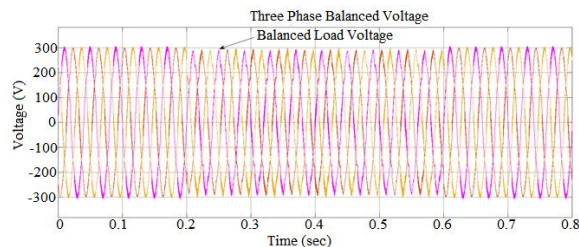

Figure 12. Simulated waveforms of Three Phase balanced Source Voltage for proposed UPFC model

The above **figure 12** demonstrates the three-phase adjusted, and unbalanced load and the source voltage of the proposed transformative intrinsic algorithm adjust control method when contrasted with another regular strategy the proposed framework gave better results and improved the damping factor
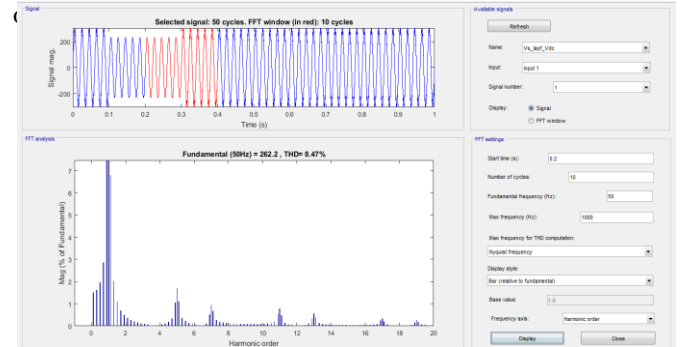

Figure 13. THD for the proposed model without UPFC controller

Figure 13 shows the proposed model without UPFC controller it accurately describes the total harmonics generation level is 8.47%.
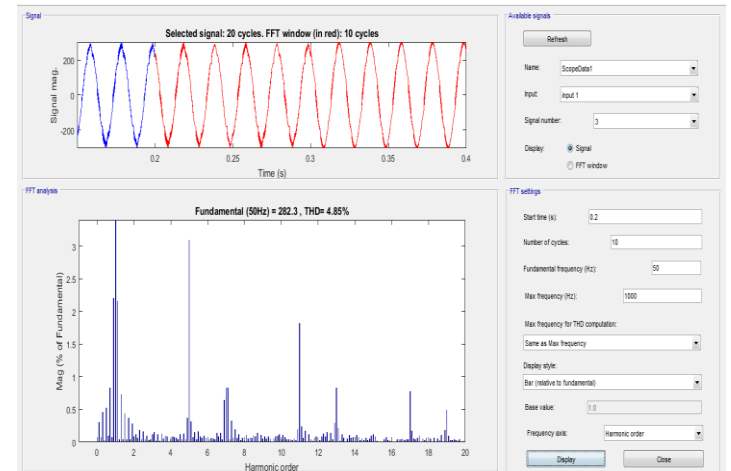

Figure 14. THD Analysis of the proposed system with UPFC controller

The above **figure 14** demonstrates the THD investigations of the proposed active power filter using the Transformative intrinsic algorithm, from the examination is gathered that the proposed power controller arrangements create the typical THD of 4.85%.

Table 2. Performance analysis for UPFC Features of proposed and existing system

Parameters	PI	ANFIS	TIA
Steady state error (%)	1.2	0.9	0.3
Switching loss (%)	0.928	0.9	0.8
With UPFC THD (%)	10.1	7.3	4.85

Table 2 shows the comparison table for the unified power flow control (UPFC) which are considered for the operating features of the existing system and proposed a system.

Table 3. THD analysis for the proposed system Without UPFC

Parameters	value
THD value without UPFC	8.47%

Table 3 shows the Total harmonics distortion for the proposed model without UPFC and the control system which produces THD value up to 8.47%
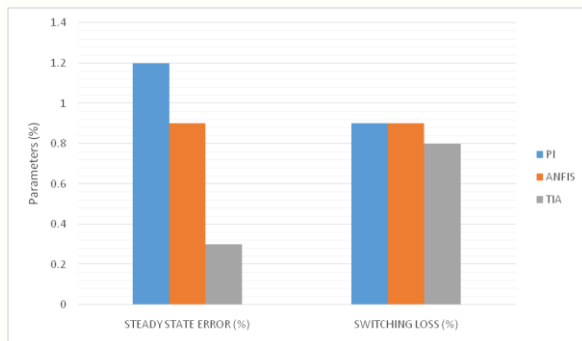

Figure 15. Performance Analysis of the UPFC system

Figure 15 performance analysis of the unified power flow control which compares various parameters like steady-state error and switching loss with conventional system .the proposed Transformative intrinsic algorithm produce a useful result.
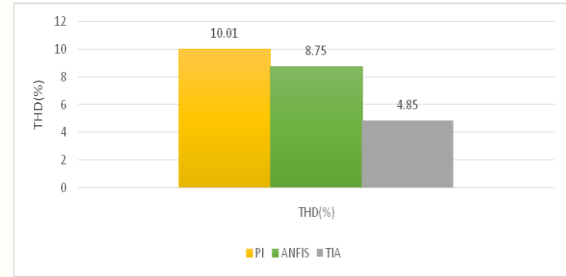

Figure 16. THD analysis

Figure 16 shows the Total harmonics distortion for the proposed model without UPFC system is 8.47 % and the with applied UPFC and optimized transformative intrinsic algorithm reduce the value from 4.85 %.

5.   **Conclusion**

Distributed Generation systems (DGs) are one of the new trends of power generation. These distributed generating units are integrated to form a microgrid to serve the loads among the locality, which is in connection with the utility grid for power exchange. This work presents the design and analysis of power quality performance improvement grid-connected bus system using novel Transformative intrinsic algorithm technique and unified power flow conditioner (UPFC) custom power device. The source system uses a voltage source converter (VSC) which performs multi-functions. Also, it utilizes a c feed-forward loop to improve the dynamic response and reduces the burden on the proportional-integral controller by regulating dc bus voltage. To control the switching sequences of VSC, a high precision quadrature control is used which extracts the fundamental current from the contaminated load current. The mathematical formulation of UPFC is corroborated by the experimental results of solar grid system under different operating conditions. To validate the simulation results of UPFC scheme tests are performed under various operating conditions. Test results show the satisfactory behavior under steady state, and dynamic conditions such as load unbalance insolation variation and voltage sag. The without UPFC Total Harmonic Distortions (THDs), 8.47% and with UPFC includes proposed Transformative intrinsic algorithm produce an

effective result 4.85 % of grid currents and voltages, are found within limits of grid code compliance.

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