FACTS FOR FAULT DETECTION AND DECISION CONTROL SCHEMES FOR WIND ENERGY CONVERSION SYSTEMS

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***Abstract*:** The aim of this research is to analyse the faults occurring in a 3 phase transmission system. There are several types of controllers used to control the faults occurring in the transmission line but they do not proved to be better in terms of efficiency and cost effectiveness. There is some power loss beyond permitted level, which is the major disadvantage that should be avoided in a transmission system and further the fault control process is more complex. To overcome all the disadvantages caused by other transmission line fault controllers the proposed method introduces the Unified Power Flow controller (UPFC) to control the faults occurring in the 3 phase transmission system which proved to be more effective than other 3 phase transmission line fault controllers. The proposed method is tested with a wind form model; a 3 phase fault is introduced in a transmission line of 500 KV. The UPFC controller effectively controls all the power parameters within their specified values thereby controlling the 3 phase fault caused in the transmission line effectively and the method is closer to 100% efficiency.

Key words: Doubly Fed Induction Generator, Unified Power Flow Controller, Fault Tolerant

1. Introduction

The Doubly Fed Induction Generator (DFIG) primary turbine takes durable nonlinearities initiated from mechanics of that turbine and therefore the dynamic of the DFIG, and also might work below a time-varying and broad operation region. The work considers a wind power generation in linearization controller supported that elaborate model by the DFIG-WT; the management object is to increase energy conversion by this method [1]. Operation of DFIG-WT absolutely does direct control systems used upon turbine generator side. The area unit typically designed via a cascade assembly approach together with a quick inner-loop for power regulate of the DFIG as well as slow down outer-loop for speed control of that drive-train. Under the valued wind speed, only in every of that critical control function is to increase the taken wind energy through variable speed process, that needs DFIG-WT should be absolutely governable and associatively conducted on optimum rotor speed in step with time-varying speed of the wind, at the same time it minimises the mechanical load [2].

The aim is to bring down the price of current made WECS and to assemble the system for operation at unity power issue. The Field Oriented Control strategy (FOC) has appealed abundant attention with the past few decades. However it suffers from the matter of the machine parameters differences that involves compromising the hardness of the control device [3]. A new scheme of sliding mode observer of Double Fed Induction Generator depends on the estimation value of the rotor resistance. The estimation of the rotor resistance depends on the use of the error between real and estimated value of DFIG in faulty conditions [4]. The advantage of this fault tolerant control is that when the fault is not tolerant an alarm signal will specify that the operator’s involvement is needed. The FTC control method is implemented and several steady and dynamic state experimental results are given [5].

The multi-viewer switch control scheme for the strong fault tolerant fuzzy control of unstable speed operation is disbursed [6]. In conflict beside the speed detector the fault-tolerant regulate methodology. This speed detector fault diagnosing has proven that the value is achieved through the remaining technique. Moreover the calculable speed is employed because of the alternative performance of the drive control [7].

High-operation vector-controlled AC motor drives are usually utilized in several industrial appliances. Although the practicality on those drives are often considerably offended by faults on power electronics and device failures, amongst different things [8].

The Doubly Fed Induction Generator Based Wind Turbine (DFIG-WT) will have sturdy nonlinearity invented from aerodynamics of that turbine and also therefore the attached dynamic of the DFIG, while may work below the time-varying and large operation domain. This work inspects the feedback linearization controlling supported the example of the DFIG-WT; the control aim is to increase power alteration by this technique [9].

The best parameters are often determined by alternative strategies like particle swarm improvement or genetic algorithmic rule [10]. Cascaded Doubly Fed Induction Machine is the fundamental of a doubly fed brushless machine. This earlier version had then developed from an arrangement supported that two divided machines to one electrical machine along with a dual-tapped stator windings wounded into a normal stator core [11].

In the meantime, the distinctive dynamic characteristics of DFIGs additionally cause new noteworthy challenges to the steadiness of recent power systems [12]. In accordance to the location of the failure purpose, the possible failure modes of the convertor area unit classified as external and internal failures [13].

A comprehensive analysis of the fault finding, fault location, associated fault-tolerant performance of Modular Multilevel Converter (MMC) below the conditions of an IGBT open circuit fault is presented. A fault identification methodology supports the current and output current observances were accustomed identifies the fault time and the faulty phase [14].

Because of direct relationship among the stator windings from that DFIG and furthermore the grid, the faults of grid can ends up in voltage sag at the DFIG terminals that instantly affects the air-gap flux and later the energy conversion method. On basis mostly upon the sort of fault, dc element or composite of dc and reverse rotating ac element within the air-gap flux is also initiated because of the voltage sag at the DFIG terminals [15]. Controlled induction motor drives whereas not mechanical speed sensors at the motor shaft have the magnetism of base value and high quality. To interchange a detector the data upon the rotor speed is extract from observed stator coil voltages and currents with in the motor terminals [16].

A fault recognition and recompense scheme supported probability ratios for networked prophetic control systems and clock resynchronization. The compensator is applied to make the network-induced time delays [17]. A comprehensive Unit Commitment (UC) model with UPFC and unsure alternative wind generation is proposed [18]. The controlled goal out of SSR alleviation is accomplished by expanding the damping system beside right opinion and infusion of sub synchronous of current and voltage towards the street by UPFC [19]. The quick advancements in power electronic devices prompted the enhancement being used of FACTs device, for example, TCSC, STATCOM, SSSC and brought together power stream controller and so on [20].

The major contributions of the project are listed below,

- To eliminate the three phase fault that occurs in the three phase transmission grid system an advanced member of Flexible AC Transmission Systems (FACTS) Unified Power Flow Controller (UPFC) is introduced.
- The Unified Power Flow Controller (UPFC) developed with shunt controller and also series controller is used in this work due to its effectiveness and versatile nature than any other controllers that can be used in an AC transmission system.
- The combination of static synchronous compensator and static synchronous series compensator in the UPFC provides minimization of loss, enhancement of load ability, voltage stability etc.
- The real and reactive power in the transmission line could be regulated by changing the magnitude and the phase angle of the series injected voltage produced by the static synchronous series compensator.
- The Shunt connected static synchronous compensator provides reactive power compensation towards the system by controlling the reactive current.
- The UPFC controls the real and reactive power in the transmission line there by controlling the voltage in the transmission line.
- The performance of UPFC in controlling the adverse effects of the three phase fault in the three phase transmission grid has been evaluated through simulation and the results were presented to prove the ideas that have been proposed.

The highlights of the proposed research are given systematically as follows:

Section 2 introduces the principle and working of the Doubly-Fed Induction Generator (DFIG) based wind turbine that is used to generate the power flow required for the test model. Section 3 introduces the block diagram of proposed system with relevant explanations and introduces the role of Unified Power Flow Controller (UPFC) in the proposed work. In Section 4 the types of faults that occur in a three phase transmission line are discussed along with their adverse effects in the transmission system. Section 5 presents the simulation results of the proposed model using MATLAB/SIMULINK along with relevant discussions. Finally, the concluding remarks of the proposed work and suggestions for further research are given in Section 6.

2.THE DOUBLY FED INDUCTION GENERATOR BASED WIND TURBINE (DFIG-WT)

The induction generators like AC electrical generators however get extra options that permit it to run at speeds lightly greater than either lowering their synchronous speed. That can be helpful for giant unstable wind turbines. As a result of wind speed will modify suddenly. Once a wind strikes a turbine, then the blades attempts to speed high, however a generator is fastened on the speed from the ability of grid and can't raise the speed. Thus massive force square measure is formulated within the gear and generator because the facility moves reverse. It produces harm on the mechanism. In case the turbine is permitted to raise the speed instantly affected by a wind, the strains measure lesser and also the wind energy is regenerate in order to help electricity

2.1 Principle of DFIG

The principle of the induction generator is that the rotor winding area unit coupled to the grid through slip rings are also consecutive source converter which controls each of the rotors and grid currents. So rotor rate will easily change from the grid regularity. By utilizing the converter to manage the currents, its potential to regulate the active and reactive power fed into the stator grid coil severally of the generator's rotating speed. Direct Torque Control (DTC) have clad turned off to higher reliability than current vector that controls particularly once large reactive currents area unit needed upon generator.

Doubly-fed generator rotors normally wound with a pair to amount three times the quantity of the stator. That implies this rotor voltages are greater and also currents severally lesser. Therefore within the ordinary ± 30% alternative speed vary round the speed, the evaluated current of a converter can consequently lesser that ends up in the lesser value on the device. The disadvantage is that control operations external the functional speed variation is not possible to the upper valued rotor voltage.

Furthermore, the voltage transient is because of the grid troubles and are likewise be magnified. So as to dodge large rotor voltages - and large flow current resultant voltages – are from terminating the diodes from that converter

In the typical three phase synchronous generator, when external supply of mechanical power influences the rotor the generator rotate, the static field made by the dc current is fed into the generator rotor winding rotates at an equivalent speed. Therefore, a frequently ever-changing magnetic flux passes via the stator windings because the rotor field rotates, inducing alternating voltage over the stator windings.

2.1.1 Sub-synchronous generating mode of DFIG

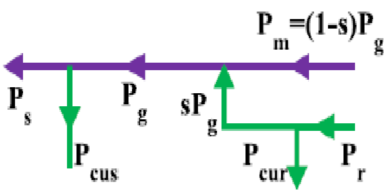


Fig 1 Sub-synchronous generating mode

For this activity of the machine, P_m is a negative, also then the speed of the rotor is a smaller compared with synchronous speed (0<s<1), Pm, wherever $P_{ag} = P_{cu2} + P_2 + P_m$. $P_{cu2} + P_m$ should negative. While P_{cu2} is positive, P_2 must to be created adequately negative in adding power to the circuit so as to form the rotor power P_{ag} negative [25]. The power flow in the grid is, P_1-P_2. The instructions of different power streams for this mode at sub-synchronous speeds are shown in fig 1

2.1.2 Super-synchronous generating mode of DFIG

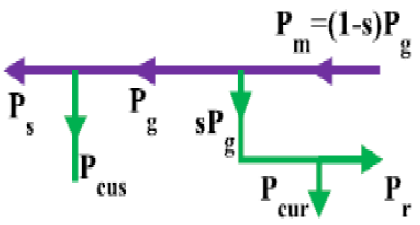


Fig 2 Super-synchronous generating mode

For this activity within the generating mode, being negative (-1<s<0) during its mode, the air hole power P_{ag} is a smaller than the power of mechanicalP_m, wherever P_m= (1-s) and P_{ag} is negative. The staying surplus energy P_{ag} is resumed through the rotor circuit to the grid once supplying for secondary losses Pcu2.

Control and activity of the DFIG WECS presents several distinctive challenges because of the extensive number of relating subsystems that cut across totally different disciplines. This interaction confirms the power equipped to the grid. The difficulties to affiliation of wind energy to the grid are tripled [21].

(a) Source Induced

The unstable nature of wind leads to flexible generation with the related power fluctuations, voltage fluctuations, and frequency deviances. Source induced fluctuations are essential on the medium-term basis within the time span of seconds to minutes.

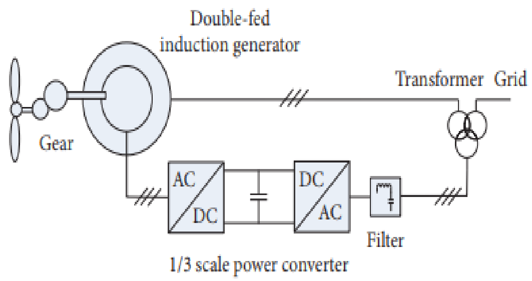


Fig 3 Configuration of a Doubly Fed Induction Generator wind energy conversion system

(b) Machine Induced.

The essential idea of the DFIG machine, as a rotating magnetic force machine, likewise results in repeated voltage fluctuations because of characteristics like magnetic saturation and hysteresis. The tower additionally causes shadow because it blocks the air flow inflicting unbalanced forces because the rotating blades from the turbines are available in direct line with the tower.

(c) Grid Induced.

These begin from the grid, grid instability and transients. Different difficulties and planned ways in which of handling them are given as follows.

3. Fault-tolerant control of DFIG

To distinguish and separate the stator-voltage sensor faults, both residuals R_1^{sva} and R_1^{svc} are initiated as

$$R_1^{sva} = \left|V_s - \hat{V}_s^{sva}\right|, \quad R_1^{svc} = \left|V_s - \hat{V}_s^{svc}\right| \quad (1)$$

To describe the approximation errors of stator-voltage, amplitude of $SVKF_a$ and $SVKFC_c$ are given correspondingly.

Further, to recognize the FDI of stator-current sensor faults, four residuals R_1^{sca}, R_1^{scc}, R_2^{sca}, R_2^{scc} are defined as

$$R_1^{sca} = \max[(i_{sd} - \hat{\imath}_{sd}^{sca})^2 + (i_{sq} - \hat{\imath}_{sq}^{sca})^2]|T_f \quad (2)$$

$$R_1^{scc} = \max[(i_{sd} - \hat{\imath}_{sd}^{scc})^2 + (i_{sq} - \hat{\imath}_{sq}^{scc})^2]|T_f \quad (3)$$

$$R_2^{sca} = \max[(i_{sa} - \hat{\imath}_{sa}^{sca})^2]|T_f \quad (4)$$

$$R_2^{scc} = \max[(i_{sc} - \hat{\imath}_{sc}^{scc})^2]|T_f \quad (5)$$

The extreme errors among the measured currents achieved from sensors and the predictable currents achieved from the periodT_f. Similarly, four residuals R_1^{rca}, R_1^{rcc}, R_2^{rca}, $R_2^{rcc}$are defined as

$$R_1^{rcc} = \max[(i_{rd} - \hat{\imath}_{rd}^{rca})^2 + (i_{rq} - \hat{\imath}_{rq}^{rca})^2]|T_f \quad (6)$$

$$R_1^{scc} = \max[(i_{rd} - \hat{\imath}_{rd}^{rcc})^2 + (i_{rq} - \hat{\imath}_{rq}^{rcc})^2]|T_f \quad (7)$$

$$R_2^{rca} = \max[(i_{ra} - \hat{\imath}_{ra}^{rca})^2]|T_f \quad (8)$$

$$R_2^{rcc} = \max[(i_{rc} - \hat{\imath}_{rc}^{rcc})^2]|T_f \quad (9)$$

3. PROPOSED SYSTEM

3.1 UPFC:

3.1.1 Equivalent circuit of UPFC:

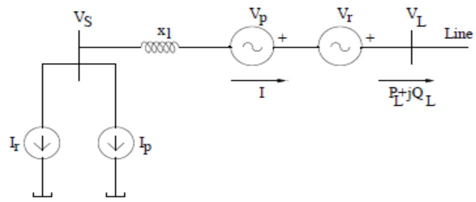


Fig 4 Equivalent circuit of UPFC

The shunt converter has active (I_p) and reactive current (V_r). The active current (I_p) isn't freelance also it is identified with V_p by relativity in steady state [22].

$$VI_p = IV_p$$

The circuit of the UPFC is seen as a 2 port network. The shunt convertor can be associated at a port whereas the series convertor will be associated in a serial line within the line on the opposite port. The last port of the voltage is meant by V_L . In case, that the series inserted voltages, $V_p$and V_r are measured to manage the reactive power within the line; such amounts are helpfully estimated at the port of the UPFC. Then the voltage $V_L$is regularly unconstrained, also the complex power, $P_L + jQ_L$

Desire didn't detail the circle, it constants VC. Certainly will be showing that $P_L + jQ_L$defines an ellipse in P-Q plane. The power S_L is assumed,

$$S_L = P_L + jQ_L = I^* V_L \quad (10)$$

$$= \frac{V_L^* - V_R^*}{-jX_L} V_L$$

Since $V_R = V_L - \frac{\delta}{2}$

$$\widehat{V_L} = \widehat{V_s} + \widehat{V_C} \quad (11)$$

$$= V\frac{\angle\delta}{2} + V_C\angle\beta$$

P_L and Q_L can be expressed as

$$P_L = P_0 + \frac{VV_C}{X_L}\sin(\frac{\delta}{2} + \beta)$$

$$Q_L = Q_0 + V\frac{V_C}{X_L} - \frac{VV_C}{X_L}\cos(\frac{\delta}{2} + \beta) + 2\frac{VV_C}{X_L}\cos(\frac{\delta}{2} - \beta) \qquad (12)$$

Since $P_0 = \frac{V^2}{X_L}$, $Q_0 = \frac{V^2}{X_L}(1 - \cos\delta)$

Defining $Q_0' = Q_0 + \frac{V^2}{X_L}$

$$= \frac{V^2V_C^2}{X_L}(2\cos\delta - 1)^2 \qquad (13)$$

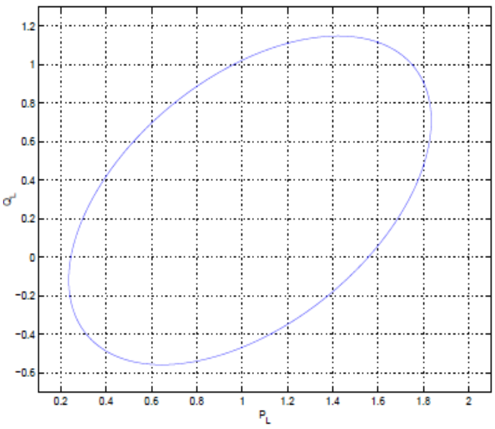


Fig 5 Operational region in the P_L- $Q_L$plane

An equation for ellipse in the centre (P_0 , Q_0 +$\frac{V^2}{X_L}$).

It is noticed that I_r are often directs the voltageV_s when it is not managed through the generator associated to the sending end. Thereby three factors V_s, P_L and $Q_L$are often directed by regulating I_r, V_C and β. It can be expected there are no limitations obligated by the instrumentality evaluations that may limit the controlling objectives.

The UPFC may be a device which may control at the same time total three factors of line current passing. This kind of recent facts device associates along the options of previous facts devices: STATCOM, SSSC. The two appliances are 2 Voltage Source Inverters (VSI's) related and separated in shunt. Besides the transmission line via the shunt transformer is serial with the transmission line via the series transformer, linked to every different by a dc linking with a capacitor.

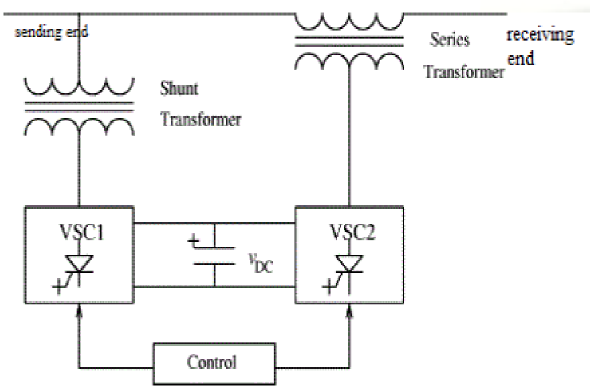


Fig 6 Model of UPFC

The shunt inverter is utilized for voltage control for the purpose of association injection on reactive power flow to the line and to adjust the important current flow changed within the series inverter and the transmission line. The series may be utilized to regulate the real and reactive line current flow injecting an opportune voltage with manageable magnitude and series with the cable.

The UPFC is that the most flexible FACTS controller expanded thus far, with all surrounding abilities of voltage direction, series compensation, and phase shifting. It will severally and extremely speedily control each real- and reactive power flows in an exceedingly transmission. It's designed as shown in Fig. and includes 2 VSCs coupled by a typical dc terminal.

The VSC device one is associated in shunt with the line by a coupling transformer; the opposite VSC converter 2 is placed in series with the transmission line via associate interface transformer. The dc voltage for each converter is given by a typical capacitance bank [32].

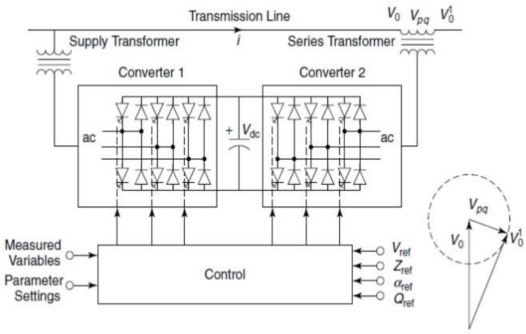


Fig 7 Implementation of the UPFC by two back-to-back voltage-sourced converters

The series convertor is controlled to infuse a voltage phase V_{pq}, in series with the line, which may be changed from zero to V_{pq} max. In addition, the phase of V_{pq} are often severally varied from 0^0 to 360^0. During this method, the series convertor trades each real and reactive power with the transmission line. Even though the reactive power produced/ consumed by the series convertor, the real-power generated/ absorbed is formed possible by the dc-energy–storage device i.e., the capacitance [23].

The shunt-connected convertor 1 is employed principally to produce the real-power of convertor 2, i.e., it derives from the conductor itself. The shunt convertor keeps constant voltage of the dc bus. So net real power drawn from the ac system is up to the losses of the both converters and coupling transformers. Additionally, the shunt convertor capacitors sorts of a STATCOM and severally regulates the terminal voltage of the interrelated bus by generating/ gripping a requisite quantity of reactive power.

3.1.2 Regulation of UPFC

Whereas the UPFC consists of two converters which are combined on the DC side and the direct of every converter is explicated as follows.

2.1.2.1 Controlling of Shunt Converter

The shunt convertor extracts a regulated current from the device. Separate element of current I_p is automated resolute by the need to adjust the real power supplied to the series convertor by way of the DC link. This power stability is implemented by control the DC capacitance voltage.

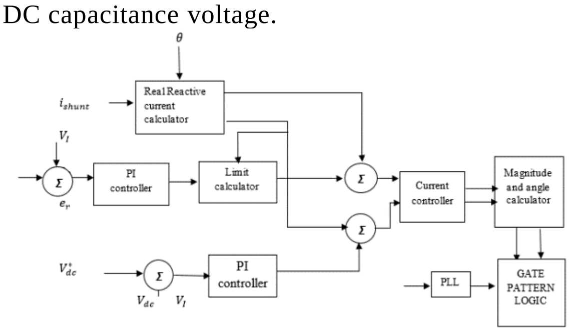


Fig 8 Block diagram of shunt controller

The other element of shunt convertor power is that the reactive current, I_r that may be directed in an exceedingly same in an STATCOM. There are two operation modes such as a STATCOM or as shunt convertor.

That are,

1. VAR system wherever the reactive current is set by the capacitive VAR control. The input signals that are achieved from current transformer generally set on performing the coupling of transformer.

2. Automated voltage regulating mode wherever the reactive current relation is decided by the voltage controller that includes a sag properties. The voltage response points are attained from capability transformer estimating the voltage V_1in to the station intake the coupling transformer.

$$\frac{di_{shd}}{dt} = -i_{shd}\frac{R_{sh}}{X_{sh}}\omega_{Base}+\omega_{Base}i_{shq} + \frac{\omega_{Base}}{X_{sh}}(V_{1d}-V_{shd}) \quad (14)$$

$$\frac{di_{shq}}{dt} = -i_{shq}\frac{R_{sh}}{X_{sh}}\omega_{Base}-\omega_{Base}i_{shd} + \frac{\omega_{Base}}{X_{sh}}(V_{1q}-V_{shq}) \quad (15)$$

2.1.2.2 Control of the series converter:

The serial introduced voltage is controlled with a vector control to confirm the move of the required phase that is conserved throughout system troubles.

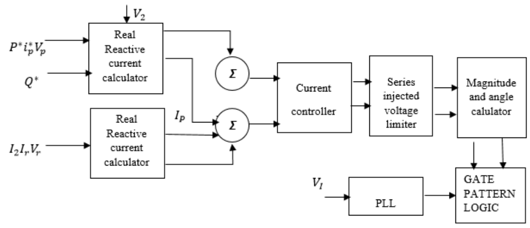


Fig 9 Block of series controller

While the convention manages the direction of the power flow within the line, then possible situations need the manager to add the device strength by power fluctuations. The various control modes are following:

1.Direct voltage introduction mode wherever this convertor just creates a voltage phase because of the concern input. A specific case is the specified voltage could be a reactive voltage in the line power.

2. Phase Angle turner conflict mode wherever the inserted voltage is phase moved with respect to the voltage by the mention input.

3. Line resistivity conflict mode wherever the series inserted voltage is regulated in extent into line current.

4. Automated power mode wherever the inputs decides such that the desired real power (P) and therefore the reactive power (Q) on a identified location within the line.

$$\frac{di_{sed}}{dt} = -i_{sed}\frac{R_{se}}{X_{se}}\omega_{Base}+\omega_{Base}i_{seq} + \frac{\omega_{Base}}{X_{se}}(V_{1d}-V_{sed}-V_{2d}) \quad (16)$$

$$\frac{di_{seq}}{dt} = -i_{seq}\frac{R_{se}}{X_{se}}\omega_{Base} - \omega_{Base} i_{sed} + \frac{\omega_{Base}}{X_{se}}(V_{1q} - V_{seq} - V_{2q}) \quad (17)$$

3.1.3 UPFC MATHEMATICAL FORM

$S_{k(k=a,b,c)}$ refers to the switching function. $S_a, S_a^{'}$ is either one or zero resembling on and off states of the switch. Based upon the principle operation of the converter $S_a, S_a^{'}$ are always complementary.

$$S_a = 1, S_a^{'} = 1, V_a = (i_a r_k + U_{dc})S_a + U_{nN} \quad (18)$$

$$S_a = 0, S_a^{'} = 1, V_a = (i_a r_k)S_a^{'} + U_{nN} \quad (19)$$

$$\therefore V_a = (i_a r_k + U_{dc})S_a + (i_a r_k)S_a^{'} + U_{nN} \quad (20)$$
$$= i_a r_k + U_{dc} S_a + U_{nN}$$

$$\therefore U_a = V_a + i_a R + L\frac{di_a}{dt} \quad (21)$$
$$= i_a(r_k + R) + U_{dc} S_a + L\frac{di_a}{dt} + U_{nN}$$

Phase “b” and phase “c” is the similar:

$$U_b = i_b(r_k + R) + U_{dc} S_b + L\frac{di_b}{dt} + U_{nN} \quad (22)$$

$$U_c = i_c(r_k + R) + U_{dc} S_c + L\frac{di_c}{dt} + U_{nN} \quad (23)$$

In maximum conditions, the three-phase power grid is stable, hence

$$i_a + i_b + i_c = 0, U_a + U_b + U_c = 0$$

Adding three formulas

$$U_{nN} = -\frac{1}{3}U_{dc}\sum_{k=a,b,c} S_k \quad (24)$$

Hence the mathematical model of the converter is

$$U_a = i_a(R + r_k) + U_{dc} S_a + L\frac{di_a}{dt} - \frac{1}{3}U_{dc}\sum_{k=a,b,c} S_k \quad (25)$$

$$U_b = i_b(R + r_k) + U_{dc} S_b + L\frac{di_b}{dt} - \frac{1}{3}U_{dc}\sum_{k=a,b,c} S_k \quad (26)$$

$$U_c = i_c(R + r_k) + U_{dc} S_c + L\frac{di_c}{dt} - \frac{1}{3}U_{dc}\sum_{k=a,b,c} S_k \quad (27)$$

In accordance to the mathematical model of the convertor, analysing the equivalent circuit, the equations in d, q directions will be concluded:

$$V_{sd} - V_{1d} = L_1\frac{di_{1d}}{dt} + R_1 i_{1d} - wL_1 i_{1q} \quad (28)$$

$$V_{sq} - V_{1q} = L_1\frac{di_{1q}}{dt} + R_1 i_{1q} - wL_1 i_{1d} \quad (29)$$

The mathematical model of the series part is as follows:

$$V_{2d} = L_2\frac{di_{1d}}{dt} + R_2 i_{2d} - wL_2 i_{2q} + V_{cd} \quad (30)$$

$$V_{2q} = L_2\frac{di_{2q}}{dt} + R_2 i_{2q} - wL_2 i_{2d} + V_{cq} \quad (31)$$

4. Types of Fault

a) Symmetric and Asymmetric Faults

-Symmetric /Balanced Faults

These are very simple faults and happen intermittently in the power systems. Those are of two types namely three lines to ground (L-L-L-G) and three lines (L-L-L). The occurrence of these faults is merely 2- 5% in power systems.

- Asymmetric Faults/Unbalanced

These are very common as they occur way more time than symmetric faults and are less severe than former faults. This mainly constitutes line to ground which is the most common fault (65-70%) , line to line (5-10%) and double line to ground (15-20%) faults.

In line to ground fault, a conductor makes contact with earth or ground. A line to line fault occurs once two conductor’s make contacts with each other mainly while lines fluctuate because of winds. While two conductors make interaction with ground then it a double line to ground faults.

b) Type of Faults on a Three Phase System

(i) L-to-G Fault (Line to Ground): A single line-to-ground (LG) fault is among the foremost common faults and experience indicates that 70-80 % of the faults that happen in power system are of this type. This procedures a brief circuit path among the line and ground. These are terribly less simple faults compared to other different faults

(ii). L-to-L Fault (Line to Line): A line to line fault occurs once a live conductor get in contact with alternative live conductor. Significant winds are the main cause for this fault throughout that swinging of above conductors may contact along. These are less simple faults and its incidence range is also between 15-20%.

(iii). L-to-L-to-G Fault (Two lines to Ground): In two line to ground faults, both lines come to interact with one another furthermore with ground. These are series faults and therefore the incidence these faults are regarding 10% in comparison with total system faults.

(iv). 3Line Fault (Three Phase): In a 3 phase fault, all 3 phases (L1, L2 and L3) are shorted along. To found the fault current at any purpose within the network, a total is created of the impedances within the network between the supplies (including the source impedance) and therefore the purpose of the fault happens. This type of fault occurs infrequently, as an example, once a line that has been created safe for maintenance by clamping all the 3 phases to earth, is accidentally created alive or once, because of slow fault clearance, associate earth fault spreads across to the opposite two phases or once a mechanical excavator cuts quickly through an entire cable. It is an important type of fault in that it results in an easy calculation and generally, a pessimistic answer. The circuit breaker valued MVA breaking capacity is based on 3- phase fault MVA. Since circuit breakers are produced in preferred ordinary sizes e.g. 250, 500 and 750 MVA high accuracy is not essential when calculating the 3- phase level of fault at a point in a power system. The system impedances are also never known accurately in three phase faults [24].

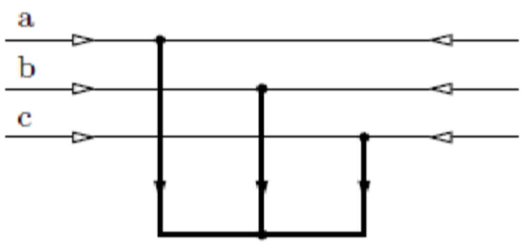


Fig 10 Three Phase Faults

By explanation a three-phase fault may be a symmetrical fault. Despite the fact that it's the smallest amount frequent fault, it's the foremost dangerous. A number of the features of a 3phase fault are a huge fault and frequently voltage level uniforms to 0 at the positioning wherever the fault leads position. The common illustration of an equal 3phase fault is proved in Fig 7 wherever F is the fault position with impedances Z_f and Z_g.

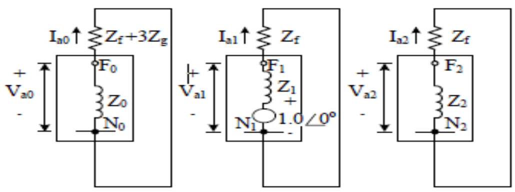


Fig 11 Sequence network diagram of a symmetrical three-phase fault

From Figure it is often noticed that only one that has an interior voltage supply is that the positive-sequence. Hence, the equivalent currents as every of the consequences are often declared as

$$i_{a0} = 0,\ i_{a2} = 0$$

$$i_{a2} = \frac{1.0\angle 0^0}{Z_1 + Z_f} \qquad (32)$$

If the fault impedance Zf is zero,

$$i_{a1} = \frac{1.0\angle 0^0}{Z_1} \qquad (33)$$

If equation is substituted

$$\begin{bmatrix} I_{af} \\ I_{bf} \\ I_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ I_{a1} \\ 0 \end{bmatrix} \qquad (34)$$

$$I_{af} = I_{a1} = \frac{1.0\angle 0^0}{Z_1 + Z_f} \qquad (35)$$

$$I_{bf} = a^2 I_{a1} = \frac{1.0\angle 240^0}{Z_1 + Z_f} \qquad (36)$$

$$I_{cf} = a I_{a1} = \frac{1.0\angle 124^0}{Z_1 + Z_f} \qquad (37)$$

Then the sequence networks are short-circuited over their own fault impedance

$$V_{a0} = 0$$

$$V_{a1} = Z_f I_{a1} \qquad (38)$$

If Equation is substituted into Equation

$$\begin{bmatrix} V_{af} \\ V_{bf} \\ V_{cf} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ V_{a1} \\ 0 \end{bmatrix} \qquad (39)$$

Therefore,

$$V_{af} = V_{a1} = Z_f I_{a1} \qquad (40)$$

$$V_{bf} = a^2 V_{a1} = Z_f I_{a1} \angle 240^0 \qquad (41)$$

$$V_{cf} = a V_{a1} = Z_f I_{a1} \angle 120^0 \qquad (42)$$

The line-to-line voltages are

$$V_{ab} = V_{af} - V_{bf}$$

$$= V_{a1}(1 - a^2) = \sqrt{3} Z_f I_{a1} \angle 30^0 \quad (43)$$

$$V_{bc} = V_{bf} - V_{cf}$$

$$= V_{a1}(a^2 - a) = \sqrt{3} Z_f I_{a1} \angle -90^0 \quad (44)$$

$$V_{ca} = V_{cf} - V_{af}$$

$$= V_{a1}(a - 1) = \sqrt{3} Z_f I_{a1} \angle -150^0 \quad (45)$$

If Z_f equals to zero,

$$I_{af} = \frac{1.0\angle 0^0}{Z_1} \quad (46)$$

$$I_{bf} = \frac{1.0\angle 240^0}{Z_1} \quad (47)$$

$$I_{cf} = \frac{1.0\angle 120^0}{Z_1} \quad (48)$$

The phase voltages are,

$$V_{af} = 0$$

$$V_{bf} = 0$$

$$V_{cf} = 0$$

And the line voltages,

$$V_{a0} = 0$$
$$V_{a1} = 0$$
$$V_{a2} = 0$$

4.1. Identifying and localize the faults

Electrical power lines are best to recognize after the issue is sometimes apparent, e.g., a tree was fallen over the benefit pole is cracked and therefore the transmitters are lying on bottom. Finding faults during a wire may be performed in the circuit unexcited or with the circuit underneath current. Fault position ways may be generally separated to termination ways, that use voltages and currents calculated at finished on cable and tracking ways that needs reviews on the size of the cable.

Termination strategies will be utilized to find the common space on the fault, to accelerate tracking on an extended either hidden wire. In easy wiring method, the fault position is usually found in the way of review of wires. In difficult wiring systems the strings is also invisible. The time field meter sends a pulse down and then reviews the reverting pulse to spot faults at the cable.

In notable telegraph wires, the galvanometers have been utilized to evaluate power; by proving at each ends on the faulted wire, the fault position may well be separated to at little miles, which allows the wire to be handled raise and rectified. The Murray and also the Varley loop were 2 styles of links for faults in wires.

In some cases an insulation fault in the wire won't display at lesser voltages. A "thumper" check set refers a highest energy, high-voltage pulse into the wire.

Fault position is completed by hearing for the volume of release at fault. Whereas the check provides to wreck at the wire site, it's sensible as a result that the faulted position could got to be re-isolated once found.

In a large impedance earthed diffusion system, a distributer could expand a fault to earth however the system continues the operating. The faulted, however stimulated, distributer will be set with a ring-type transformer collection of all the phase cable of the circuit; Just the circuit including a fault to earth can display a net unequal power. To create the earth fault current which easy to find, the earth resistance of the scheme could also be switchable among 2 rates.

5. Simulation & Results:

The tests were conducted using MATLAB/SIMULINK software. The Simulink model shown in fig 9 is the test model used to obtain the results proposed in this work. The voltage and current waveforms of each block and their explanations to prove the ideas proposed in the work are discussed below.

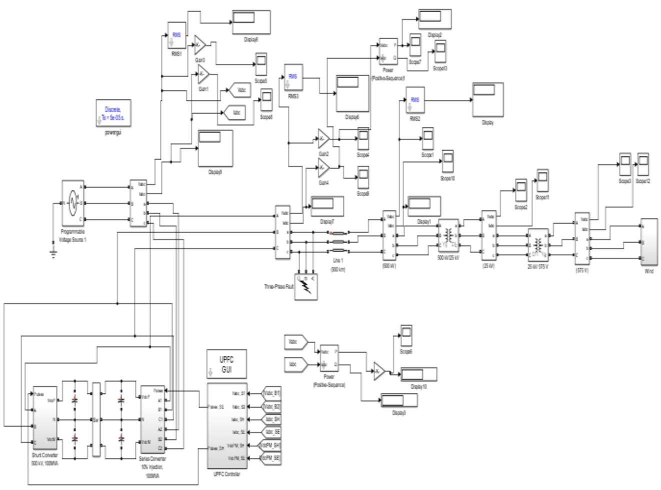


Fig 12 Simulation diagram for fault tolerant of DFIG with UPFC

The system under sturdy consists of a wind turbine that generates 575 V, this voltage obtained from the wind farm is further stepped up to 25 KV by using a transformer that is placed next to the wind farm in the test model. The 25 KV obtained from this transformer is fed to another high power transformer and is boosted up to a voltage level of 500 KV.

5.1. Wind Turbine waveforms:

The result for the wind turbine is follows,

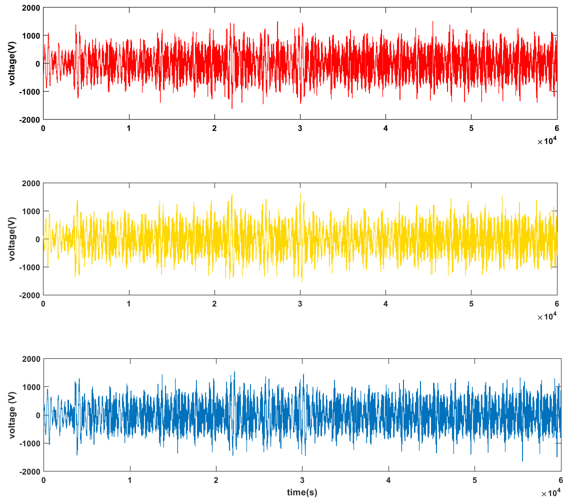


Fig 13 Simulation result of Voltage obtained from wind turbine

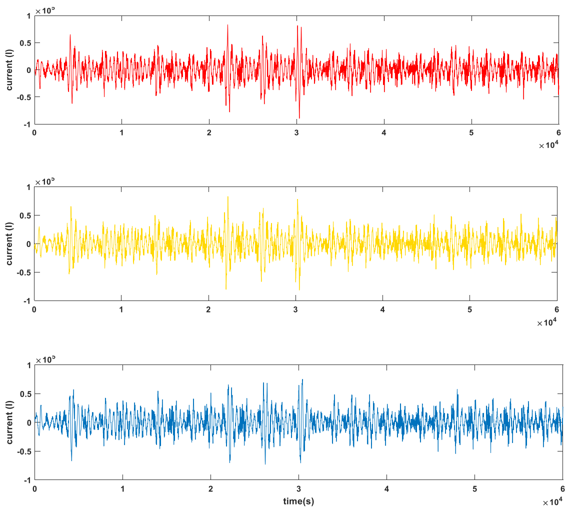


Fig 14 Simulation result of current obtained from wind turbine

Fig 13 shows the Voltage generated by the wind turbine. The wind turbine generates a voltage of 575 V within a time span of T=0.5 Seconds.

Fig 14 shows the current generated by the wind turbine. A current of 50 Ampere was generated when the time reaches T=0.5 S.

Waveform of 25 KV Transformers:

The result for the transformer is follows,

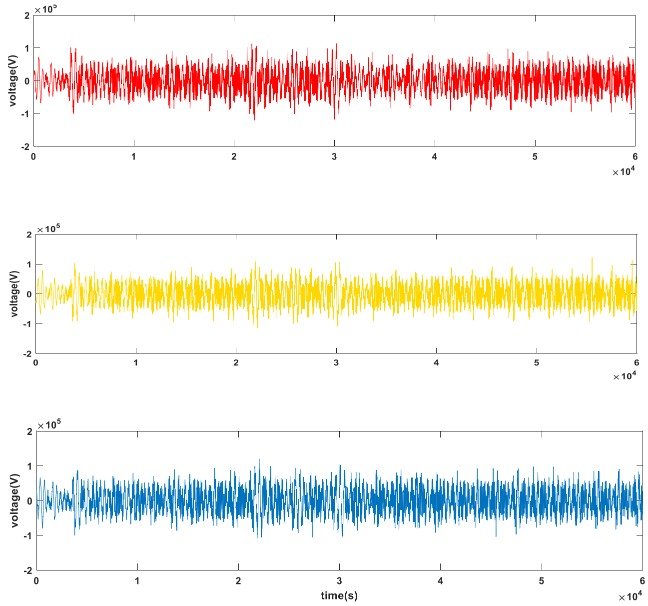


Fig 15 Simulation result of voltage obtained from 25KV transformer

The Transformer gets the 575 V as input and step-up the voltage to 25 KV, the voltage initially increases gradually and settles at 25 KV at T=1 S.

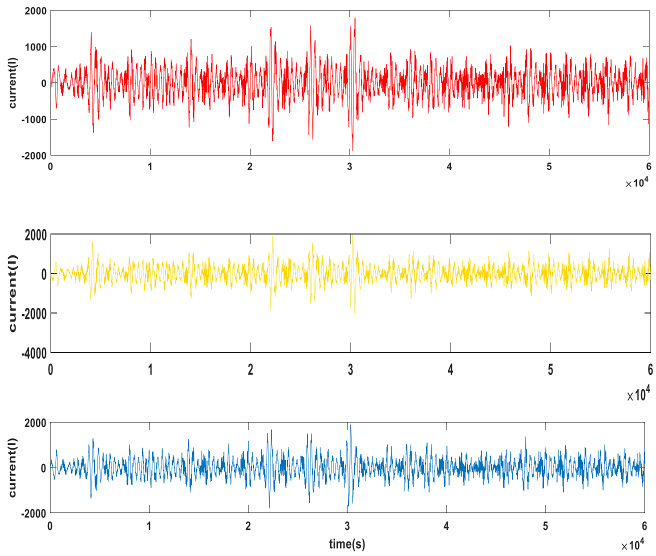


Fig 16 Simulation result of current obtained from 25KV transformer

The Current is stepped to 75 Ampere and remains constant throughout the entire functioning of the transformer.

5.2. Waveform of 500 KV Transformers:

The result for the transformer id follows,

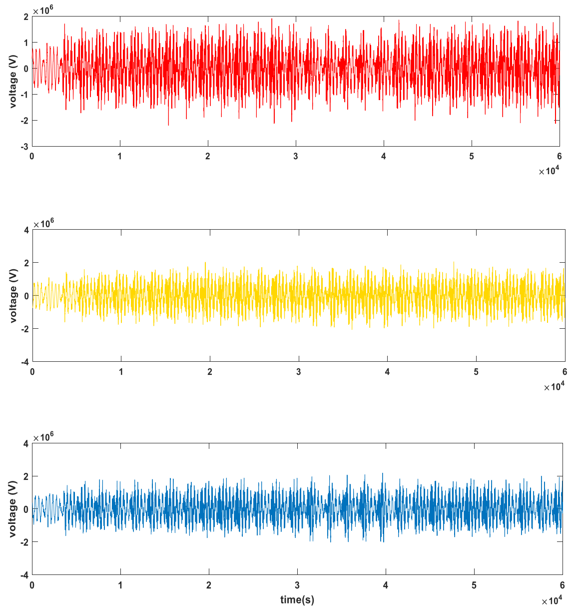


Fig 17 Simulation result of voltage obtained from 500 KV transformers

The above figure 17 shows the waveform of the voltage stepped up by the other transformer to 500 KV. The voltage level reaches the required level at T=0.2 S.

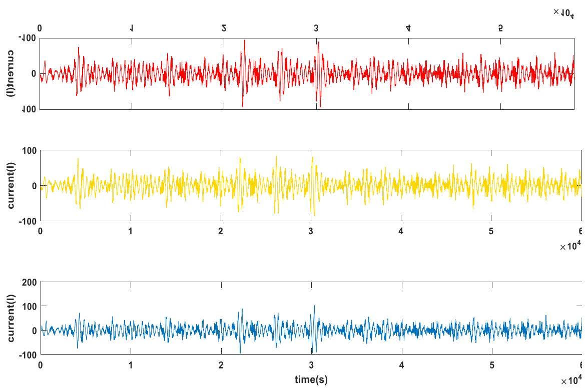


Fig 18 Simulation result of current obtained from 500 KV transformers

The current raises to 100 Ampere at T=1.5 S. The current value increases gradually and reaches a maximum of 100 Ampere and again it reduces its level to a constant current of 75 A, and remains constant throughout the process, as shown in the current output figure 18.

The 25 KV voltage obtained from the wind farm is thus boosted up to 500 KV. This 500 KV output voltage is fed to a grid system with three phase transmission line. In this three phase transmission line a three phase fault is introduced which results in high peak in the level of voltage and current with distortion.

5.3. Fault Voltage & Current:

The result for fault voltage and current is follows,

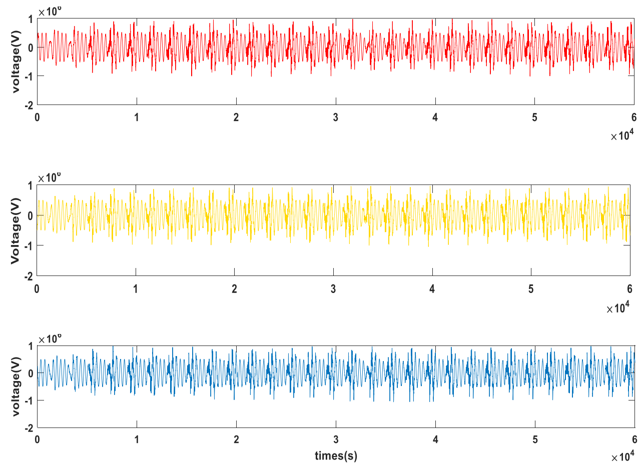


Fig 19 Simulation result of Fault Voltage after introducing three phase fault in the grid

The Waveform of the Fault Voltage after the introduction of three phase fault in the grid was exhibited in figure 19. The voltage initially remains somewhat constant till T=0.2 , and then high voltage spikes and transients occur continuously resulting in voltage instability that could cause severe damages to the transmission system hence this voltage spikes and instability has to be controlled by using suitable controllers the reduces their hazards in the transmission line.

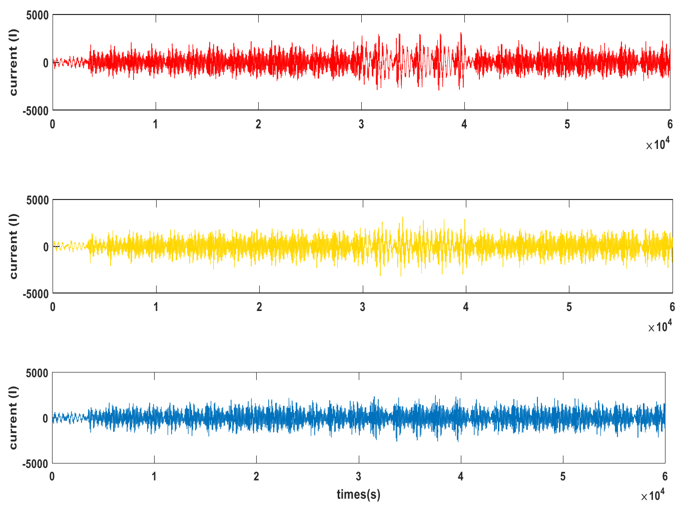


Fig 20 Simulation result of fault current after introducing three phase fault in the grid

The current in the grid also loses its stability and varies in greater extent that may cause hazardous effects in the transmission system. The current waveform as a result of three phase fault in the grid is shown in figure 20.

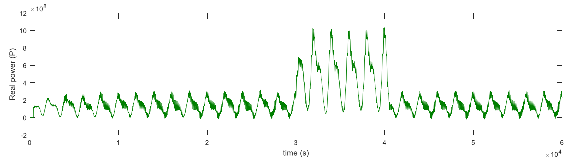


Fig 21 Simulation result of Real power of the grid after the introduction of three phase fault in the Grid

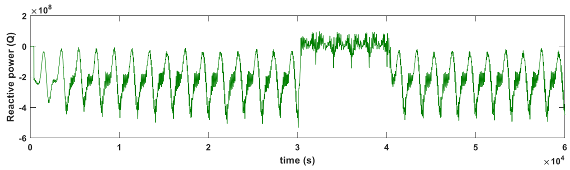


Fig 22 Simulation result of Reactive power of the grid after the introduction of three phase fault in the Grid

The three phase fault in the grid has adverse effects on the Active or Real Power (P) and the Reactive Power (Q) in the transmission line. The above figures 21 and 22 shows the Real Power (P) and the Reactive Power (Q) in the transmission line after the introduction of three phase fault in the grid. Both the Real Power and Reactive Power raises to greater values than allowed during the transmission of power in a transmission line. Higher transients can be observed at T=1.5 S in both P and Q.

These two devices are two Voltage Source Inverters (VSI's) connected respectively in shunt with the transmission line through a shunt transformer and in series with the transmission line through a series transformer, connected to each other by a common dc link including a storage capacitor. A MATLAB/SIMULINK model of the UPFC controller is shown in figure 23.

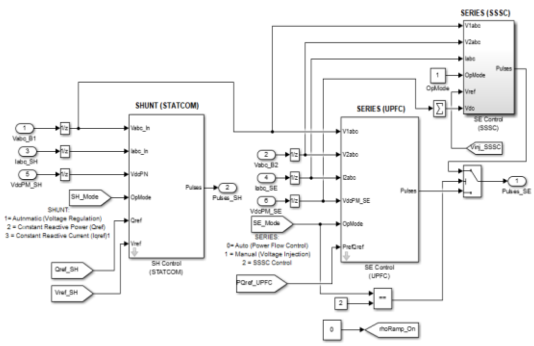


Fig 23 Simulation diagram of UPFC

Direct voltage injection mode: The converter simply generates a voltage phase in response to the reference input.

Phase Angle Shifter Emulation mode: The injected voltage is phase shifted relative to the voltage by an angle specified by the reference input

- Line impedance emulation mode: The series injected voltage is controlled in proportion to the line current.
- Automatic power flow control mode: The reference inputs determine the required real power (P) and the reactive power (Q) at a specified location in the line.

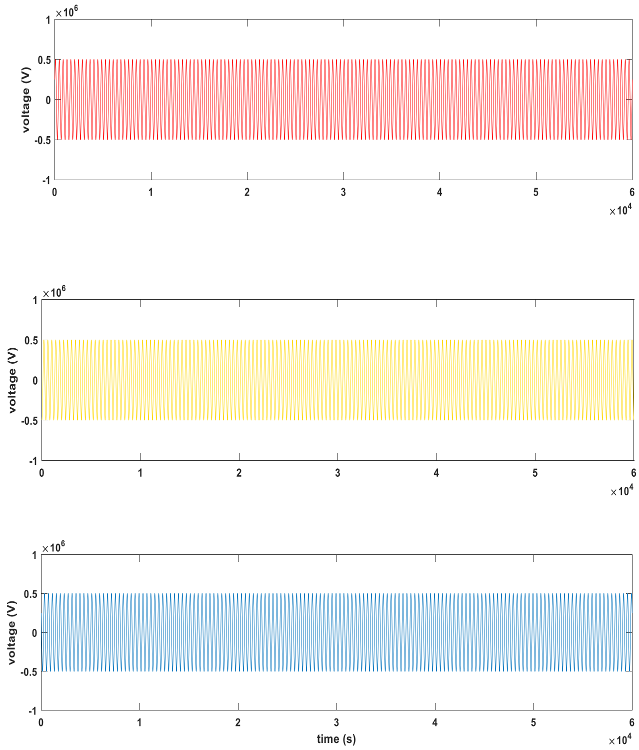
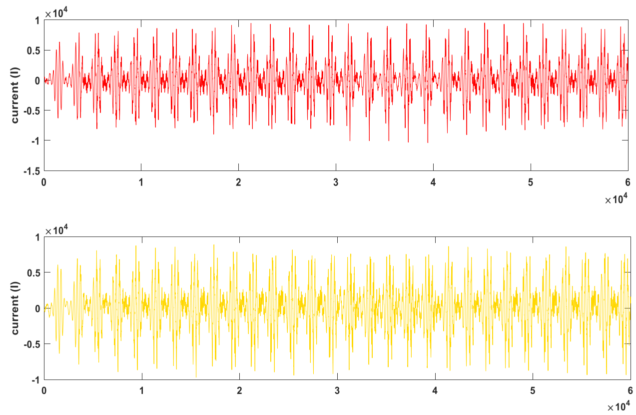


Fig 24 Simulation result of Grid voltage after the three phase fault that caused supernormal peaks and distortions in the grid voltage was controlled by the introduction of UPFC Controller



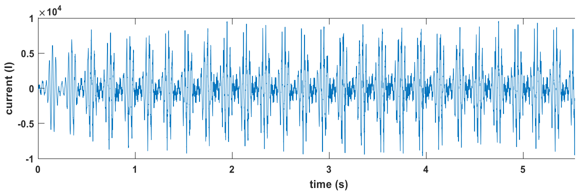


Fig 25 Simulation result of Grid current after the three phase fault that caused unusual peaks and distortions in the grid current was controlled by the introduction of UPFC Controller.

Figures 24 and 25 shows the voltage and current waveforms obtained from the grid after UPFC controller is introduced to control the magnitude of the voltage in the transmission line. Figure 24 shows the result of using UPFC and the control it has over the voltage. The spikes and transients that were caused in the transmission line voltage due to the three phase fault were successfully ruled out by the UPFC controller and the voltage settles down to normal level quickly than in any other fault control used in the three phase transmission line.

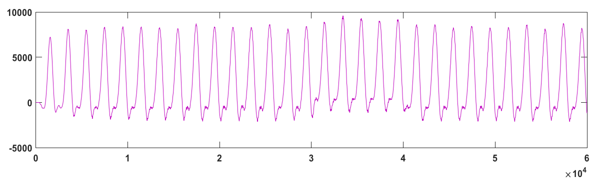


Fig 26 Simulation result of Real Power (P) after the three phase fault that occurred in the transmission line was successfully controlled by the UPFC Controller

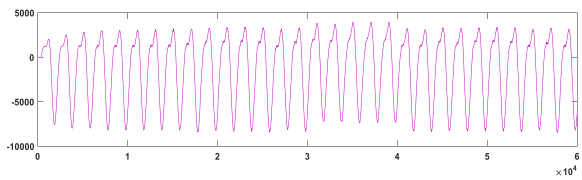


Fig 27 Simulation result of Reactive Power (Q) after the three phase fault that occurred in the transmission line was successfully controlled by the UPFC Controller

The obtained Simulation results in figure 26 shows the effectiveness of Unified Power Flow Controller over other controllers in controlling the Real Power (P) in the watts that a Real Power is permissible in a three phase transmission line. Figure 27 shows the Reactive Power (Q) after it is controlled to its permissible VAR (volt-ampere-reactive) by the control powered over it by the UPFC.

6. Conclusion:

The testing and analysis of controlling the three phase fault occurring in a three phase transmission line/Grid was performed using a UPFC Controller. The basic control strategy is such that the shunt converter of the UPFC controls the transmission line reactive power (Q) and the voltage. The series converter controls the real power flow (P) in the transmission line. The shunt converter provides all of the required reactive power during the power flow. The Voltage and Current in the grid are maintained within their limits avoiding unusual spikes. The real and reactive power flow of the transmission line was maintained at constant levels. Thus the effects of the three phase fault that occurred in the transmission line were successfully eliminated and all the line parameters are controlled and maintained within their specified limits by the UPFC Controller.

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