Confronting to Non-linear Events and Enhancing the System on the Basis of PV-UPFC

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Abstract. Electric power systems are exposed to various types of Power Quality (PQ) disturbances. A PQ assessment is necessary to maintain the accurate operation of electrical sensitive equipment and to ensure its maintenance. Therefore, there will be a need to investigate and mitigate PQ events. In our modern times, we have noticed that AC distribution systems suffer from very consistent pollution to use a lot of loads as these loads generate harmonics that reduce the power quality of the system. The main objective of this paper is to conserve PQ through Flexible Alternating Current Transmission Systems (FACTS) such as Unified Power Flow Controller (UPFC) using Photovoltaic (PV) arrays. In addition, the system is designed during a generator source with a wind power generator where the results are compared before and after the control on each bus with the display of harmonics of current and voltage. Finally, the results presented in this paper indicate the ability of the UPFC to control the event and inflation and reduce the harmonics.

Keyword: Voltage, Current, Power Quality, UPFC, PV, Harmonic, Bus, VSC, MATLAB/Simulink.

1. Introduction
The issues and solutions of PQ problems depend on the site, so PQ appreciation is a significant of sensitive projects. Beneath normal circumstances, PQ is essentially a load problem. Mostly that growth in the control systems manufacture and power electronics, the linear loads is majority once load, now dominated via the majority for nonlinear patron loads. So the PQ for the system is the same as the customers' solicitudes as far as the attention of the supply authorities is concerned. PQ evaluation has become important into nearly all electrical utilities around the world. This is due mainly for the fact that customer has grow to be more sensitive equipment and it's related to large-scale operations and grids. In result, equipment failure and process shutdowns for changes that have never been of great concern may be very costly in changes in the quality of the power [1]. Therefore, the most vulnerable electronic device is the PQ of the components of the classical power system. The main source for PQ disturbances today is the enforcement for electronic technology, in addition to the change the mode of operation and benefit from them in addition to these technologies. The Alternating
Current (AC) power supply device is designed to perform at a sinusoidal voltage with a regular frequency 50 Hz [2]. A flicker, harmonic, transient, voltage notch, voltage swell and voltage sag these are classifications events of PQ. Ability quality research is the investigation of different wonders that causes control quality occasion to happen and the improvement of extenuation strategy. The PQ disturbances are establishing each time there is a sizeable alternate in the supply voltage importance, supply frequency, and/or waveform deviation because of numerous varieties of faults, nonlinear loads, switching of heavy hundreds, strength electronics converters etc [3].

The non-stop energy systems enlargement and a load of varying nature have imposed high requirements in defensive equipment's, especially related with pace and accuracy. these are crucial factors for fault clearance. If a fault isn't nicely detected and eliminated, vast harm or an electricity gadget black out can also take location. The behavior of defensive devices may trade with the diverse styles of loads including linear and non-linear hundreds related with the distribution gadget. The simulation method is one of the widely used studies approach to version and simulates diverse energy first-rate events [4]. To enhancement the events that affected the quality of electrical power, some of which cause (voltage sag, voltage swells, harmonic, transients, voltage flicker, short duration interruptions and voltage unbalance) of the voltage or current and the consequent impact of these events on the quality of energy in the network and do not forget there are many new techniques to resolve these events and vary each technique for the other in terms of efficiency and ability to enhancement the quality of the power in the network, whether it is improvement by the FACTS such as UPFC [5].

PQ troubles inclusive of contemporary harmonics, voltage swells, voltage sags and voltage unbalance are extra full-size for single phase device. At the identical time, diverse lively filtering answers had been elaborated to the PV mesh-related systems, which might be firstly intended to current quality matter [6]. Shortage of traditional power sources is now imposing electricity engineers to discover alternate power sources which might be reliable, cost powerful and renewable. Out of various renewable energy resources, PV supply is obtaining excessive momentum because of its speedy diminishing reducing capital cost, its capability to offer requisite dc voltage and below operation cost [7, 8, 9]. These PV systems are inserted to network over a solar inverter. These PV solar reflectors cause different PQ issues in the allocation circuit [10]. The researchers reported that the preferable solution to eliminate the main PQ troubles have been announcing in the past ten years. Power plants have gradually changed their capabilities according to requirements and expectations that have been increased by the significant increase in the use of energy-sensitive electronic equipment. After the Negative Energy Filters (NEF), the Active Power Filter (APF) proved its ability to preserve the PQ [11, 12]. In the same field, the introduction of APF hybrid to overcome the shortcomings of APFs and NEFs [13]. All PQ issues have been directly concerning to voltage and current fluctuations. Energy conservation has become the quality of both cases is impossible at any special energy conditioners. The dealing with PQ problems concerning to voltages through the use of APF series and are dealing with the problems created by the current harmonics using APF [14]. However, to obtain the requirements for improving PQ, the installation of both the APF series and the adapter alone isn't a cost-effective resolution. Line voltage conditioner in which each shunt and series APFs were linked in the back [15]. This back-top system topology is named as a standard UPFC adjuster that has the ability to maintain current and voltage harmonics. The UPFC utilizes two sources of voltage inverters linked at a joint the Direct Current (DC) capacitor [16]. The UPFC is utilized in an energy allocation phase whereas UPFC is utilized in an energy conveyance system. UPFC necessity for equipping balance series or shunt reparations as energy transference operates in deformation empty environment [17]. Therefore, the primary aim for UPFC is at recompense for current load PQ problems and to voltage PQ problems in the supply aspect. However, UPFC is unable to recompense power current for because it has no power stockpiling in DC-Link [18].

2. Unified Power Flow Controller (UPFC)
The UPFC is a new type belongs to FACTS group and it contains both the shunt and series converters. The Static Synchronous Compensator (STATCOM) represents the shunt and the Static Synchronous Series Compensator (SSSC) represents the series which both are functioned from a common dc link.
Its functions are to permit a bidirectional flowing of active power between the series outputs of SSSC and shunt outputs of the STATCOM without any external source as shown in the figure. The principles of UPFC consists of two back-to-back converters called VSC2 and VSC1, which are operated from the DC connection supplied via the DC power capacitor. These run as a perfect transformer to an AC where real energy can flow freely either in the direction among the AC terminals of the two transformers and each transformer can generate or absorb the reactive energy independently as its output station [19].

![Figure 1: Principle of UPFC](image)

The VSC is linked into transmission lines by shunt converters and the other is linked in series through the series converters. The DC tip is coupled with two VSCs and this makes a way for the exchange of active energy among the converters. Therefore, VSC provides the prime position of the UPFC via injecting a control angle voltage and a phase angle in the series with the lines through the injection adapter. This injected voltage run as a source of synchronous voltage. The current of the transmission lines flows by this voltage source, which causes in active and reactive energy interchange among it and the AC system. Mutual reactive energy is generated in the DC station internally via the converter. The real energy interchange in the AC power station is converted to DC energy, which shows at the DC energy connection as real power request and the VSC1 is to provide or absorb the real energy required via VSC2 back to the AC via VSC1 along with the transmission line transmission by a linked transformer. In addition, VSC1 can also generate or absorb interactive energy that can be controlled if demanded and thus provides separate shunt reactive compensation to the lines. Consequently, the VSC1 may be run in a unit PF or for its controller to share reactive energy with lines separate of the reactive capacity interchanged via VSC1. Clearly, there may be no reactive energy flow during the UPFC DC bind [20].

2.1. UPFC Mathematical Modelling

The UPFC is a generalized AC transfer controller that has a lot of multi-functional abilities and therefore, able to perform compensation functions and control selectively or simultaneously for different individual line controllers and compensators. A UPFC consist of two solid state synchronous VSC coupled through a common dc link as shown in figure 2. The serve VSC represents the central task of UPFC. It is operated as SSSC in order to generate an additional voltage added to the AC bus voltage through the series transformer. The output shunt voltage (Vsh) responsible for reactive current regulation. The shunt converter provides a leading current to the network when Vsh leading the voltage Vi which leads to equipping to the network. On the other hand, when Vsh lagging the bus voltage Vi then it performs an inductive process leads to absorption [21].
\[ A = \pi r^2 \]  
\[ = \pi (2b)^2 \]  
\[ = 2463 \text{ square meter} \]  
\[ P_t = \frac{1}{2} \rho \times A \times V^3 \, cp \]  
\[ = \frac{1}{2} \times 1.23 \times 2463 \times 12^3 \times 0.59 \]  
\[ \text{Where} \, 0.59 \text{ bet's Constant} \]  
\[ = 1544 \, kw \cong 1.5 \text{mw} \]  
\[ \text{rpm Calculation} \]  
\[ \text{rpm} = \frac{Hz \times v \times TSR}{\pi D} \]  
\[ \text{Where} \, v = \text{Velocity of air 12m/sec}. \]

\[ V_{abc \text{ in p. u.}} = \frac{K V_{\text{actual}}}{K V_{\text{base}}} \]  
\[ V_{abc \text{ in p. u.}} = \frac{132000}{76210} = 1.72 \text{p. u.} \]  
\[ I_{abc \text{ in p. u.}} = \frac{I_{\text{actual}}}{I_{\text{base}}} \]  
\[ I_{abc \text{ in p. u.}} = \frac{209.95}{121.21} = 1.732 \text{p. u.} \]  
\[ \text{Active Power or Real Power} = 41726.8 \text{kw} \cong 41 \text{MW} \]  
\[ \text{Reactive power} = 11000 \text{kVAR} \cong 11 \text{MVAr} \]  
\[ \text{Power KVA} = \sqrt{kW^2 + kVAR^2} \]  
\[ \text{Power KVA} = \sqrt{41726.8^2 + 11000^2} \]  
\[ = 43152.35 \cong 43 \text{ MVA} \]  
\[ \text{Transmission line current calculation} \]  
\[ I_{\text{line}} = \frac{48000 \times 1000}{132 \times \sqrt{3}} = 209.95 \text{A} \]  

\[ \text{Figure 2: General structure of UPFC [21].} \]
3. Problems Statement
The faults and turmoils in electrical ability devices discompose negatives. The perturbations contain voltage sag, power frequency variations, voltage flickers, transients, harmonics, interruption and voltage swell. These situations cause problems for the energy system and even instability until the fall apart. Furthermore, the continuous call for inside the grid electric energy device as long as heavy load ensuing in system anxiety. PV-UPFC may be implemented in those cases to keep away from stabilizing fluctuations and voltage breakdown. Those controllers have precise reimbursement features and unique while linked through the PV cell apparatus.

4. Simulink Model
Generic UPFC designs revolve about the concept of connecting converters from the back to the power line. The multi-directional utilize of these back-to-back converters mainly focuses on both current and voltage troubles, leading to PQ disturbances. A combination of power filter features to labor simultaneously in general schematic points, where shunt and series filters are in a back-to-back relationship with the DC-Link capacitor. Focusing on the ability to conserve PQ, this work suggests a UPFC configuration that is associated with PV panels as shown in figure 3. The UPFC can preserve voltage interruption as well as reducing harmonics with the PV cells. When there is an energy outage on the part of the network, the PV sources linked via DC-Link will be capable to provide the energy demanded the load. In appendix-A, the parameters of this system are shown.

Figure 3. (a) One-line diagram for the second case study and (b) Simulink model for second case study by PV-UPFC.
5. Simulink Results and Discussion
The system is simulated and the results presented before the control of the PV-UPFC technology and after its control. This system consists of two generators, one is the primary generator and another wind generator where PV is added to this technique. During the second case study, the non-linear load is connected to Y grounded and the fault is connected to one line to ground specifically on phase B. This case represents the implementation of the proposed controller PV-UPFC on this paper where the effect is taken of events on buses for the voltages, currents, real and reactive power; figure 3 shows the Simulink implementation of this case using MATLAB/Simulink. In figure 4 (a) shows the impact bus 1 due to events without controllers and, in figure 4 (b), shows the ability of PV-UPFC to improve PQ, but the sinusoidal wave suffers from some transient and some distortion during operation the system. Where the fault takes phase B to ground within a period of time (0.2-0.3) second.

![Simulink Implementation](image)

**Figure 4:** Effect the events on a bus 1 for Simulink model without a controller and (b) It with a controller by PV-UPFC.
The same results are taken for bus 2 showing the effect of these events on current, voltages, on real and reactive power before they are encountered as shown in figure 5. Comparison of the results controlled by this technique as shown in figure 5 (b), the ability of the UPFC technique to respond to events better appears to reduce distortion and transient condition at bus 2 compared with the figure 5 (a).

Figure 5: Effect the events on a bus 2 for Simulink model without a controller and (b) It with a controller by PV-UPFC.

In figure 6 (a) shows the effect of events on the bus 3 in the Simulink model. These events are encountered using PV-UPFC the enhancement results for this technique are shown in figure 6 (b), showing the extent of difference before and without improvement of these events.
Figure 6: Effect the events on a bus 3 for Simulink model without a controller and (b) It with a controller by PV-UPFC.

It is also important to take into consideration the wind generator and to show the effect of load and fault on this generator. In figure 7 (a) shows the effect of events on the bus 4 in the Simulink model. These events are encountered using PV-UPFC the enhancement results for this technique are shown in figure 7 (b), showing the extent of difference before and without improvement of these events.
Figure 7: Effect the events on a bus 4 for Simulink model without a controller and (b) It with a controller by PV-UPFC.

In addition, figure 8 (a) shows the effect these problems of system the voltage harmonics are to THD= 0.83% without a controller and when improving by PV-UPFC the THD= 0.24 % as shown in figure 8 (b).
Fig. 8: (a) Harmonics voltage without a controller and (b) with a controller by PV-UPFC

Also when comparing the results, the current harmonics without a controller as shown in figure 9 (a) become THD= 5.67%, but when a controller of these events the current harmonics to the ratio THD= 0.03% shown in figure 9 (b).
6. Conclusion
The model was simulated prior to the introduction of UPFC technology where it shows that the voltage drops of the source within the specified period and the magnitude of the gain relative to the current on phase B. Thus, the technology of UPFC was introduced to control the drooping voltages and the magnification in phase B. The measurements were taken on all the buses. Control and remote control by UPFC. Through the results presented in the paper indicates the ability, effectiveness of this technique where it has done very well, the extent to which harmonics are reduced relative to current and voltages, and the extent of its control over events affecting the system.

7. Appendix
Appendix-A: The Parameters of Simulink Model

| Parameters                      | Value                                           |
|--------------------------------|-------------------------------------------------|
| Grid Voltage                   | $V_S = 132e3 \text{ Vrms}$                      |
|                                | $P_n = 1.5 \times 10^3 \text{ VA}$              |
|                                | $V_n = 690 \text{ Vrms}$                        |
| Asynchronous Machine           | Mechanical power $= 1.492 \times 10^6 \text{ W}$ |
|                                | $L_m = 13.04/377 \text{ H}$                     |
| Frequency                      | $f = 50\text{Hz}$                               |
| Source impedance (RL)          | $1 \Omega, 1 \times 10^{-3} \text{ H}$         |
| Wind Speed                     | Time $= [0 \ 0.5 \ 0.95] \text{ s}$             |
|                                | Amplitude $= [5 \ 9 \ 12]$                      |
| Transformer                    | 550/132 KV (Yg/D)                               |
| Three-phase short-circuit level at base voltage | $1000 \times 10^6 \text{ VA}$                |
| X/R ratio                      | 10                                              |
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| **Base voltage (Vrms ph-ph):** | 1000*10^6 VA |
|-------------------------------|--------------|
| **Three-phase Series L Branch** | L = 1e-3 H |
| **Fault LG**                  | Phase B to Ground |
|                               | [r_1, r_0] = [0.1153 0.413] Ohms/km |
| **Three-phase \( \pi \) section line** | [l_1, l_0] = [1.05e-3 3.32e-3]H/km |
|                               | [c_1, c_0]= [11.33e-009 5.01e-009] F/km |
|                               | Line length= 1 km |
| **Three-phase series RLC Load** | V_n= 132 KV_r.m.s |
|                               | P = 80*10^6 w |
|                               | Q_L=10*10^6 var |
|                               | Q_C=100 var |
| **DC bus capacitor**          | C_pv = 4000e-6F |
| **Capacitor initial voltage** | 7e3V         |

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