ENHANCEMENT OF POWER QUALITY BY THE COMBINATION OF D-STATCOM AND UPQC IN GRID CONNECTED TO HYBRID SYSTEM

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ABSTRACT

Demand for electricity increasing, to meet energy requirement nonconventional energy sources are utilized. In this paper combination of WES and PVS generates power and voltage at PCC with grid instantaneously. Due to integration of hybrid system into the grid poses power quality issues. Basically hybrid system is the combination of two power generating system that will provide power continuously. PVS converts solar radiation into electric energy and WES converts wind energy into electric energy. The goal of this study is concerned on power quality problems i.e voltage/current fluctuation, flickers, distortion, damping, harmonics and other parameters are voltage/current sag/swell are analyzed. To mitigate the power quality issues combination of FACTS Devices such as D-STATCOM and UPQC are used and simulated in SIMULINK/MATLAB Software.

Keywords: Power Quality (PQ), Wind Energy System (WES), Photo Voltaic System (PVS), Integrated Wind and Solar Energy System (IWSES), Hybrid Energy System (HES), Distributed Static Compensator (D-STATCOM), Unified Power Quality Compensator (UPQC)

Cite this Article: Sumithra M and Sujatha B C, Enhancement of Power Quality by the Combination of D-STATCOM and UPQC in Grid Connected to Hybrid System, International Journal of Electrical Engineering & Technology, 10(5), 2019, pp. 39-49. http://www.iaeme.com/IJEET/issues.asp?JType=IJEET&VType=10&IType=5

1. INTRODUCTION

In everyday life needs of electric energy increasing with increase in sustainable growth and social progress, the generation of electricity with non conventional energy sources was a more challenging task to the generating stations to meet energy requirements. In order to fulfill the power requirement, alternative non conventional energy generating systems are used. The non
conventional energy sources such as WES, PVS, and geothermal, hydro, co-generation systems are used to fulfill the necessary power requirements for increased population growth and industrialization also eco-friendly as per the environment safety regulation guide lines. Conventional energy resources like coal, petrol, natural gases and fossil fuels produce radial and extreme affects on environment, which may cause global warming and green house effects in atmosphere. The necessary of integration of the non conventional energy sources like wind into existing renewable energy system minimizes the atmospheric effects by conventional energy system [1,2].

PV system converts solar energy into electricity. The main problem of PVS is unable to extract energy in bad weather conditions. WES transforms mechanical energy from wind into electrical energy to generate electricity. These power change caused by the effect of turbulence, wind shear, and tower shadow. Induction generator is one of the simplest methods of running a WES and it is connected directly to the grid system. The wind energy systems present a technical challenge like stability, voltage regulation, and PQ issues [2].

Recently, the Power quality issue became more significant and their effect is very important on power distributors, manufacturers and consumers. For smooth operation of sensitive equipments the voltage quality is very important. The power quality problems are defined as voltage/current dip/raise, harmonic distortion, unbalance and transient. Which affects customer equipment, as well as malfunctioning in their operation of power generation. To mitigate the power quality issues several power electronic compensating devices like SVC, D-STATCOM, UPFC, UPQC, SSSC etc are used [3]. In this paper combination of D-STATCOM and UPQC is employed to enhance the power quality issues caused by grid connected hybrid system.

2. HYBRID ENERGY SYSTEMS
The energy generated by two or more energy resources to provide consumers is known as hybrid system. It can also define as “Power system designed to fabricate or extract energy by the use of two or more energy resources.” HES have good efficiency, reliable, and low cost. In this paper PVS and WES combined to generate electricity. PVS and WES have more advantages than other renewable energy resources. Both wind and PV energy available abundantly in nature with less maintenance cost.

2.1. PV Energy System
PVS generates energy by using solar radiation energy. Solar energy available abundantly in nature, which is free of cost as well as pollution free, less maintenance cost. The main drawback of PVS is unable to extract energy in bad weather conditions, but efficient compared to other energy sources. Initial investment cost is high, less emission and long life span [5].

2.2. Wind Energy System
WES generates electricity has low generation cost, low maintenance cost, less maintenance cost, good reliability, low emission, long life, more efficient and provides power continuously but needs huge investment[4].

3. GRID TOPOLOGY
The total power generated by IWSES is the addition of the energy extracted by PVS and WES. This is expressed as,
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\[ P_{IWSES} = N_{WES} * P_{WES} + N_{PVS} * P_{PVS} \quad \text{(1)} \]

Where,
- \( P_{IWSES} \) = Power generated by integrated wind and PV System.
- \( P_{WES} \) = Power generated by WES
- \( P_{PVS} \) = Power generated by PVS
- \( N_{WES} \) = No. of wind turbine
- \( N_{PVS} \) = No. of PV modules

The power generated by WES is,

\[ P_{WES} = \frac{1}{2} \rho A_{WES} U^3 \quad \text{(2)} \]

Where,
- \( P_{WES} \) = Power extracted by WES watts (W)
- \( \rho \) = Density of air (kg/m³)
- \( A_{WES} \) = swept area by air (m²)
- \( U \) = velocity of air (m/s).

The size of PV module is determined. Hence the required power consumption must be estimated. Therefore power generated by PVS is,

\[ P_{PVS} = Iso(t) * A_{PVS} * \eta(PVS) \quad \text{(3)} \]

Where,
- \( Iso(t) \) = Time required to isolation (kw/m²)
- \( A_{PVS} \) = Area per PV module (m²)
- \( \eta(PVS) \) = Efficiency of PV module

Total efficiency is calculated as

\[ \eta(PVS) = M * K \quad \text{(4)} \]

Where,
- \( M \) = Average PV energy on tilted panel per annum.
- \( K \) = Performance ratio.

The total cost of the IWSES is depending upon the number of wind turbines used and number of PV panels used. Hence total cost is calculated as,

\[ C_{IWSES} = \left( N_{WES} * C_{WES} \right) + \left( N_{PVS} * C_{PVS} \right) \quad \text{(5)} \]

Where,
- \( C_{IWSES} \) = Total cost of integrated IWSES in Rs
- \( C_{WES} \) = Cost per wind turbine in Rs
- \( C_{PVS} \) = Cost per PV panel in Rs
- \( N_{WES} \) = No. of wind turbine used
- \( N_{PVS} \) = No. of PV modules used
IWSES needs high initial investment cost, less maintenance cost. The cost of the system depends on the type of system chosen, availability of source and power costs in that area. The cost of the system is reduced by increasing the use of renewable energy resources. Therefore generation of PV and wind energy generation is increased. Hence the cost of the whole system is reduced.

4. ANALYSIS OF POWER QUALITY ENHANCEMENT

Power quality enhancement by D-STATCOM: The D-STATCOM consists of a 3Φ VSC, a capacitor is connected on its DC link with BESS these are connected to PCC. The compensated current of variable magnitude and frequency component is provided by D-STATCOM to the PCC. The combination of WES and PVS, 3Φ source, D-STATCOM and non-linear load with BESS are connected to PCC. The CCVS converter based D-STATCOM injects current into the grid or PCC, so that the source current becomes harmonic free and in-phase with the source voltage [3]. The general block diagram of D-STATCOM is shown in Figure 1.

![Figure 1 General block diagram of D-STATCOM](image)

Power quality enhancement by UPQC: The sensitive quality of electric energy to the consumers is produced by the use of UPQC. UPQC consist of integrated DVR and D-STATCOM connected through a capacitor, which act as a dc link to limits the harmonic within desired limits enforced by IEEE-519 standards. The DVR is series part of UPQC balance the voltage level and minimize distortion on the load side. The D-STATCOM is a shunt part of UPQC provides compensated load reactive power (Q), harmonics is reduced and load is balanced by balancing the source current [6]. General block diagram of UPQC as shown in Figure 2.

![Figure 2 General block diagram of UPQC](image)

The equation for Real and Reactive power of the line is,

\[ P = \frac{Vin Ve}{X} \sin \delta \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1) \]

\[ Q = \frac{Vin Ve \cos \delta - V^2 r}{X} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (2) \]

Where,

Vin = Input voltage.
Ve = Output voltage.
X = System impedance
5. SIMULATION AND RESULT
The grid connected hybrid system with UPQC and D-STATCOM modeled for a non linear load in MATLAB/SIMULINK. The system parameter is shown in the Table 1.

Table 1 Simulation parameters

| SI. No | Parameter                                      | Rating                                                                 |
|--------|------------------------------------------------|------------------------------------------------------------------------|
| 1      | Source                                         | 3-Phase, 50Hz, 415V.                                                   |
| 2      | Induction generator/motor                      | 1.5MVA, 50Hz, 415V, p=4, Rs=0.0021, Ls=0.06, Rs=0.0019, R=0.0016      |
| 3      | Inverter parameters                            | Vdc=700, Switching frequency=28KHz, Cdc=0.750μF, R=1Ω                  |
| 4      | PV Cell                                        | Isg=1000W/m², Isc=7.34A, T=298K                                      |
| 5      | Shunt Inverter LC filter (UPQC)                | L=15H, R=5Ω, C=100μF                                                 |
| 6      | Series Inverter LC filter (UPQC)               | L=10Mh, R=5Ω, C=10μF                                                 |
| 7      | DC link for UPQC                               | C=750μF                                                               |
| 8      | Line Length                                    | 200km(seg)                                                            |
|        |                                                | 1000km(well)                                                         |
| 9      | Load                                           | P=10KW QL=1KW                                                        |

Figure 2 General block diagram of UPQC

Figure 3, Figure 4 Figure 5 and Figure 7 show the internal model of D-STATCOM, UPQC and complete model of grid connected IWSES using UPQC, D-STATCOM respectively. D-STATCOM generates lagging or leading current for maintaining the fixed terminal voltage, reducing harmonics and balancing load. The D-STATCOM consisting of 3-leg IGBT based on CCVS and DC capacitance. The DC capacitor acts as an energy storing device and provides reactive power compensation. Whereas UPQC consisting of a combination of DVR and D-STATCOM. Both DVR and D-STATCOM consisted 6-thyristsors.
connected together in each module & dc link is provided in between DVR & D-STATCOM. Further to improve PQ of the system, UPQC compensate fluctuations to protect sensitive loads and also to enhance reliability of the system. Figure 5 shows simulation results for sag mitigation.

Figure 3 Internal structure of Hybrid system

Figure 4 Internal structure of UPQC
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Figure 4 Simulation model of Hybrid system for sag mitigation

(a) Source current

(b) Hybrid source current

(c) D-STATCOM current

(d) UPQC current
Figure 5 Sag mitigation

(a) Without D-STATCOM and UPQC
(b) With D-STATCOM and UPQC

Figure 6 FFT Analysis for sag mitigation
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Figure 7 Simulation model of Hybrid system for swell mitigation

(a) Source current

(b) Hybrid source current

(c) D-STATCOM Current

(d) UPQC Current
Figure 8 Swell mitigation for Hybrid system

Figure 9 FFT analysis for swell mitigation
6. CONCLUSION
This paper presents the Hybrid Source, D-STATCOM, UPQC and non-linear load are connected at PCC. Due to integration of WES and PV system power quality problems exists and connecting non-linear load Total Harmonic Distortion (THD) occurs in the system. Power quality problems like sag, swell, fluctuation, flicker is mitigated by using D-STATCOM, UPQC with filter. Simulation is carried out using MATLAB/SIMULINK.

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