Sag and Swell mitigation and Power quality improvement in grid connected hybrid system using UPQC

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Abstract — Power quality is the major problem that always affects the cost and efficiency of the transmission and distribution system. The effective solution for this problem is to use the power conditioning devices to compensate the power quality problems. These power conditioning devices are made of power electronic converters. These imperfections are present in both the source and the load ends which are compensated by the Custom power devices like UPQC. The UPQC interfaced with hybrid system provides the controlled and standard output power even for the renewable sources which are the major developing trends in electrical power system. In this paper the solar and wind are the hybrid energy system which is connected to the transmission lines. The UPQC contains a DC link which controls the Sag and Swell, LG Fault and improves the power quality of the system. This system is executed in the MATLAB/SIMULINK.

Keywords — Solar, Wind, PMSG, Voltage sag, Voltage swell, UPQC, DG.

1. Introduction

There are some technically challenging issues that occurs during the renewable energy integration with the existing power system. These issues involve voltage regulation, stability, power quality problems, etc. The power quality is the most important feature in which the customer focuses. Power quality is also affected by the transmission and distribution losses. Electricity generation from the renewable sources has significantly increased due to limitless existence of sources such as solar and wind energy. The energy from the renewable sources varies continuously; there will be a lot of difficulty in interfacing renewable sources with the normal traditional electric grid. Due to the low efficiency of renewable sources, these generating systems are designed for small scale generation. Power electronic devices are widely used for the DG to connect it to the nominal grid which requires a special technology for the metering infrastructure. UPQC is a power electronic device which helps to mitigate the power quality related issues in hybrid systems. UPQC is the custom power device which mitigates the power quality issues like harmonics, sag, swell, power factor, voltage and current fluctuations.

The series filter of UPQC filters the voltage harmonics where as the shunt part mitigates the load current quality. UPQC is the combination of both the series and shunt filters. Series filter is used to compensate the voltage whereas shunt filter compensates the current but it fails to compensate the voltage interruptions due to absence of source in it. It is very important to maintain constant frequency and voltage when a system is connected to the grid to maintain better power quality and reliability of power system. Solar and wind energy generation systems are the two main renewable sources used in this paper as the hybrid generating system.

In this paper UPQC is used for the mitigation of sag and swell that occurred in the transmission line a part from the hybrid system interfacing into the grid. In voltage sag the nominal voltage decreases...
from 10% to 90% of the RMS voltage whereas in voltage swell the phenomenon is exactly opposite to that of voltage sag. UPQC works under the principle of power angle control to improve the quality of power that is sent to the local consumers. The details about hybrid system is provided in Section II, the details about UPQC is provided at Section II and the simulation results using MATLAB/SIMULINK are provided at Section III.[1-2]

2. MATHEMATICAL MODELLING
   A. SOLAR MODELLING
   In this system the solar is used as the two diode equivalent circuit of solar PV module. The two diode model of Solar PV is provided in the fig. 1. The equivalent circuit consists of photo current \( I_{ph} \), two diodes \( D1 \) & \( D2 \), diode currents \( I_{d1} \) & \( I_{d2} \), Series Resistance \( R_{se} \), Shunt Resistance \( R_{sh} \), Shunt Current \( I_{sh} \), Series current \( I=I_{ph} \) and Output Voltage \( V \).[3]

   \[
   I_{sh} = \frac{V + (R_{se} \times I_{ph})}{R_{sh}} \tag{1}
   \]

   \[
   I = I_{ph} \left[ \exp \left( \frac{V + R_{se} \times I}{N \times V_{j}} \right) - 1 \right] - I_{d1} \left[ \exp \left( \frac{V + R_{se} \times I}{N \times V_{j}} \right) - 1 \right] \frac{V + R_{se} \times I}{R_{se}} \tag{2}
   \]

   \[
   I_{D1} = I_{S1} \left[ \exp \left( \frac{q \times V}{N_{1} \times K \times T} \right) - 1 \right] \tag{3}
   \]

   \[
   I_{D2} = I_{S2} \left[ \exp \left( \frac{q \times V}{N_{2} \times K \times T} \right) - 1 \right] \tag{4}
   \]

   The parameters of the solar PV module are given in the tabular form listed below.
Table 1: Solar PV parameters and ratings

| Parameter                      | Value   |
|--------------------------------|---------|
| Maximum Power(PMax)            | 245W    |
| Voltage at PMax                | 30.5V   |
| Current at PMax                | 8.04A   |
| Short circuit Current          | 8.73A   |
| Open circuit Voltage           | 37.5V   |

### B. WIND MODELLING

![Wind generation block diagram](image)

The vertical axis wind turbine with permanent magnet synchronous generator (PMSG) is used in this paper. The parameters of the wind model are listed in the tabular form given below.[4].

Table 2: Mechanical parameters of wind modeling

| Parameter                  | Symbol | Value and Units |
|----------------------------|--------|-----------------|
| Wind turbine rotor radius  | R      | 1.25m           |
Length of Blade | L | 2.5m
---|---|---
Swept area of Wind turbine | A | 6.25m²
Air density | ρ | 1.22kg/m³
Pitch angle | υ | 0

Table 3: Electrical parameters of wind modeling

| Parameter | Symbol | Value and Units |
|-----------|--------|-----------------|
| Stator resistance | Rs | 12.875Ω |
| Inductance on D axis | Ld | 0.0085H |
| Inductance on Q axis | Lq | 0.0085H |
| Permanent magnet flux | λθ | 0.175Wb |
| Pole pairs | P | 2 |
| Moment of inertia | J | 0.0008kgm² |

The power equation for wind modeling is given by

\[
P_m = \frac{1}{2} \frac{C_p}{2} \rho A U_w^3
\]

(5)

Where \( P_m \) is mechanical power from the turbine, \( C_p \) is the constant of turbine, \( \rho \) is the air density, \( A \) is the swept area of the turbine and \( U_w \) is the velocity of the wind.

d-q modeling of PMSG is used for converting wind energy to the electrical energy which is
connected to the solar PV system for Hybrid modeling.

C. **UPQC Modelling**

UPQC is the combination of the back to back connection of series and shunt filters which injects voltage and current into the system respectively. The control strategy used is hysteresis control method for the compensation of sag and swell and LG fault induced by the renewable hybrid system.

![UPQC circuit](image)

**Fig. 3: UPQC circuit**

The control strategy used in this model is the Hysteresis control technique for both the series and shunt filters. Hysteresis control is an automatic current control technique which switches to high when the current is high and switches to low when the current is zero.[2]

![Hysteresis controller](image)

**Fig. 4: Hysteresis controller**
3. Simulink model

![Simulink model of UPQC with Hybrid system](image)

The Distribution system is designed with Grid of 380V 50Hz. The Swag is injected into the grid from 0.01 to 0.05 seconds with 0.5 times the peak voltage of the normal grid. The swell is injected from 0.05 seconds to 0.08 seconds with 1.5 times the peak voltage of the normal grid. LG fault is injected for about 0.2 seconds from 0.2 to 0.4 sec.

4. Results and Analysis

The sag, swell and LG fault which is present in the input voltage waveform are mitigated in output Voltage waveform. The distorted current waveform in the Input current is absent in the output current waveform. The power quality is improved in the output wave forms which is supplied to the load ends. The results for the simulation are given below with output waveforms.

![Solar PV output](image)
5. Conclusion

The load side and source side disturbances in voltage like Sag and Swell is mitigated by using hysteresis control strategy of UPQC and hence provided the sinusoidal voltage waveform at output with the peak voltage equal to the supply voltage of the distribution grid. Hybrid system is designed to provide additional source to the load side. The control technique is used not only to mitigate sag and swell but also to compensate the line to ground fault (LG fault) and provide the accurate complete sinusoidal waveform of output voltage and hence helps to increase the quality of power at load ends. UPQC fails to mitigate the voltage interruptions at the input side which can be controlled by providing a controlled DC source at the DC link capacitor.
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