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Stability and Power Quality Improvement in Grid Connected System- A Review

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Abstract:

The modern power system contains complex circuitry involving transmission lines, generators, loads and transformers etc. As the power demand has increased exponentially over the last few decades, transmission lines are nowadays overloaded. The transmission capacity is limited majorly due to problem of transient stability, which arises due to the increased loading of long transmission lines. A severe fault on this system may cause instability. This leads to FACTs devices being installed in the system. The scarcity of power can be met by using renewable sources like Solar Energy, Wind energy etc. The Solar Energy systems also called PV system can be used in isolated or grid connected mode. PV system has numerous benefits and its use has been increasing in recent years. Beside electricity shortage, a more vulnerable issue in modern power system is related to quality of power delivered. A good quality of power ensures smooth operations of electrical utilities. Non-linear loads in the grid produce harmonic distortion in the grid. This reduces the power quality in the system. Good Power Quality is immensely important for both industrial and domestic sectors. In this paper a review of Power Quality problems and FACTs devices is discussed.

Keywords: *Flexible AC Transmission System (FACTS), PV (Photo Voltaic), Maximum Power Point Tracking (MPPT), Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC).*

I. INTRODUCTION

Huge influx of energy demand in the developing nations is countered at the cost of natural resources which are depleting at a very fast rate. So there is urgent need to move towards the non-conventional sources of energy like solar, wind energy etc. These power generating systems can be used standalone or can be connected to the grid to meet the increasing load demand [1]. The power quality issues which includes the voltage sag, voltage swell, harmonic distortion, transients, frequency variations, multiple notches, voltage flicker etc are the sensitive energy sources in grid connected renewable energy sources. [2]. And thus, due to the power quality issues, the grid will experience loss of generation which may cause grid instability. One of the major issues of power quality issues, harmonic distortion is caused by non-linear loads connected to the electrical power system possess a major challenge [3]. Aharmonic is a voltage or current at a multiple of the fundamental frequency of the system, produced by the action of non-linear loads such as rectifiers, discharge lighting, or saturated magnetic devices. The harmonic current flowing through the power system will cause power loss in transmission lines and reduces its usable load capacity. Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives,

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and torque pulsations in motors. FACTS controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines [4]. In next section a short discussion of Power Quality issues is discussed.

II. Power Quality Issues

Following are some major PQ issues in a modern power system [5]:

A. Voltage Sag

When the RMS (Root Mean Square) voltage less than the (0.10-0.90 per unit) nominal voltage at the rated power frequency is termed as voltage swell. Sag is caused by sudden changes in loads such as faults, motor starting and sudden increases in source impedance, usually caused by a connection failure.

B. Voltage Swell

Voltage swell is a rise in voltage (1.10-1.80 per unit) greater than the time range (0.5-30 seconds). The main causes of voltage swells are a sudden reduction in load on a circuit with the damaged voltage regulator.

C. Voltage Interruption (Short & Long)

It refers to loss of system voltage ranging from few cycles to few minutes. An electrical transient is a short term excess of voltage/current (0.10 per unit)in an electrical circuit which only lasts milliseconds, which can occur electrical, data and communication circuits. The transmission line switching, reactor and capacitor bank switching are the causes of power

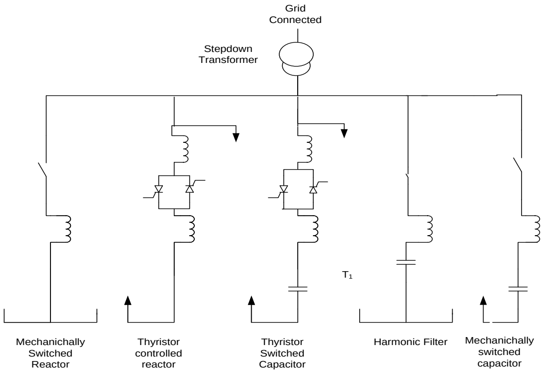

Fig. 1 Static Var Compensator (SVC)

system switching events in voltage transients Frequency variation.

III. Power Quality Improvement

Power quality, involves sinusoidal voltage and current of rated frequency. Good power quality can be defined as a steady supply voltage that stays within the prescribed range, steady AC frequency close to the rated value and smooth voltage curve waveform (resembles a sine wave) [5]. An electrical device (or load) may malfunction, fail prematurely or not operate at all. Due to Power Quality issue low power quality leads to number of consequences such as

- Higher energy usage
- Higher maintenance costs
- Equipment instability and failure

A. Introduction to FACTs Devices

Flexible Ac Transmission System (FACTS), is recently emerged as a critical component in power system controllers due to advancement in area of power electronics. These devices such as SVC, STATCOM, SSSC etc. are able to act in a very fast manner for controlling the network condition due to this reason FACTS devices is being used to mitigate the power quality issues like voltage sag, swell, harmonics etc. of the connected system [6]. Some critical FACTS devices are introduced below.

a) Static VAR Compensator (SVC)

Fig. 1 shows the circuit configuration of a SVC. It is controllable device that is used to control voltage at the particular bus to improve the voltage profile of the system. It provides reactive power support to the connected bus. By proper controlling reactive VARs, the voltage at a particular bus is maintained at its rated value. The compensation is achieved by controlling the firing angle of the thyristors as per requirement [7]. In shunt compensation, SVCs have a key role which improves steady state and transient voltage dynamics. Its performance is much better than fixed shunt compensation. Beside voltage control, SVCs are also used to damp power swings,

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reduce system losses and improve transient stability by optimized reactive power control. The reactance which is variable is given by Eq. (1)

$$B_{SVC} = \frac{X_L - \left(\frac{X_C}{\pi}\right)(2(\pi-\alpha) + Sin2\alpha)}{X_C X_L} \quad (1)$$

b) Thyristor Controlled Series Capacitor (TCSC)

Fig. 2 shows the circuit configuration of a TCSC. A TCSC is also an important FACTS device. It is used with long transmission lines for controlling the line reactance in modern power systems. TCSCs perform various functions such as power flow control, system losses reduction, lowering of unsymmetrical components, short-circuit currents reduction, provide voltage support at a particular bus. TCSC also play critical role for mitigating Sub Synchronous Resonance (SSR), damping power oscillation and enhancing transient stability of the connected power system [8].

$$X_{TCSC} = \frac{X_C X_L(\alpha)}{X_L(\alpha) - X_C} \quad (1)$$

where, $X_{SVC} = \frac{1}{jB_{SVC}}$

c) Static Compensator (STATCOM)

Fig. 3 shows circuit configuration of STATCOM. Static Compensator or STATCOM is a power electronic device. It uses switching devices such as IGBT, GTO etc., which can be gate commuted. The main function of STSTCOM is to control the reactive power flow in a power network and thereby increasing the stability of power network. STATCOM is basically shunt connected device. STATCOM is also termed as Static Synchronous Condenser (STATCON). It is also an important member of the Flexible AC Transmission System (FACTS) [9].

d) Static Synchronous Series Compensator (SSSC)

Fig. 4 shows the circuit configuration of SSSC. It is one of the newest FACT device used for series compensation of power transmission system. In the modelling it is shown as a synchronous voltage source because it can generate voltage synchronous to the connected system and also injects this variable magnitude sinusoidal voltage of proper frequency

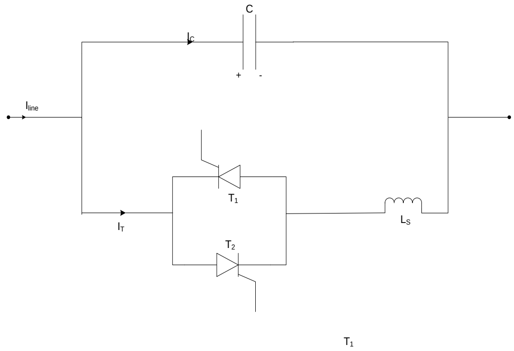

Fig.2 Thyristor Control Series Capacitor (TCSC)

and controllable phase angle, in series with a transmission

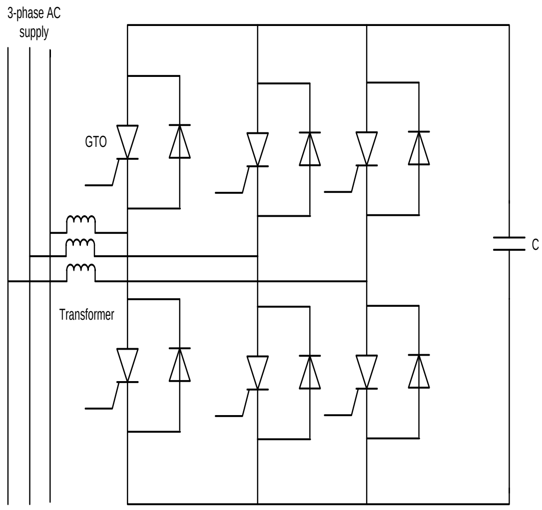

Fig.3 Static Compensator (STATCOM)

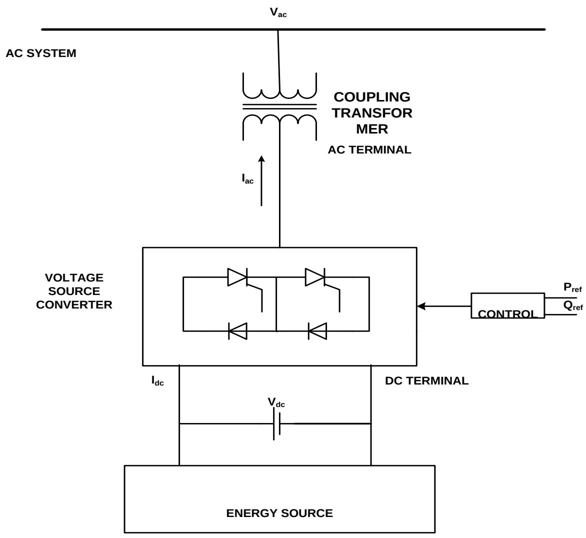

Fig.4 Static Synchronous Series compensator

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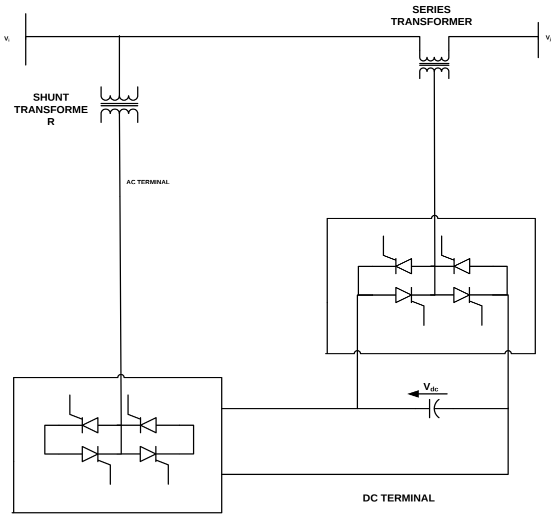

Fig. 5 Unified Power Flow Controller (UPFC)

line voltage. Voltage is injected in phase quadrature with the line current to boost the transmission line voltage. The effect of inserting an inductive or capacitive reactance is realized by injected phase voltage at different phase angle w.r.t line current of the transmission line. There are losses in the inverter because of high switching speed in the SSSC. Thus a small part of injected voltage is made in phase with the transmission line current. The variable reactance thus obtained is used to change dynamically the transmission line reactance which affects the transmission line power flow.

e) Unified Power Flow Controller (UPFC)

Fig 5 shows the circuit configuration of UPFC. UPFC combines the topology of series and shunt compensation. It can be used to improve dynamic stability as well as steady state stability and transient stability. In this UPFC series and shunt devices can be independently controlled. UPFC can be a combination of shunt compensating devices such as Static Synchronous Compensator (STATCOM) and series connected device such as Static Synchronous Series Compensator (SSSC). UPFC is an useful utility FACTS device for power system stability improvement.

IV. Stability And Power Qualty Improvement in Grid Connected Pv Sysytem

Today contribution PV power to the grid is increasing at a very fast rate. In grid connected PV system the grid voltage drops during fault in the grid. In order to protect inverters the PV system voltages drops even more and this creates a huge trouble in the recovery of grid at such low voltages. Hence modification in PV control is necessary. Paper [11] presents research on LVRT (Low Voltage Ride Through) of grid connected PV inverter when grid fault occurs. In this paper when the PCC voltage falls below the rated value due to fault, still by proper control the PV power stations is not disconnected from the power system. The proposed control technique makes us of suppressing negative sequence current to achieve stability in the system.

In [12] three phase modified dual stage inverter is used for integrating PV and grid System. The technique mainly focuses on series resonant three phase isolated DC- DC converter in a dual stage inverter. Approximately 96 - 97.5 % efficiency is measured for the DC-DC stage. In this paper it is shown that inverter is responsible for MPPT as well as grid current.

Stability control of dispatch able grid-connected PV System is studied in [13]. This paper focuses on requirement of energy storage for improving power quality of system for improving power quality of system [13]. This paper also shows that energy storage system can damp out the power fluctuations in the PV system, due to which power quality of the overall system is improved.

In [14] a new topology named Modular Multilevel MMI (HB) Topology is introduced for single stage grid connection of Photovoltaic (PV) system. The Modular multilevel inverter, MMI (HB) uses half-bridge sub modules. This paper also emphasis on future potential PV application in the electrical energy market.

Real time study on power flow in the grid connected system which is based on real time output characteristics is shown in [15]. This paper reviews the effect of voltage variation in solar plants due to factors like low sunlight during cloudy days, snowy days, during nights. Detailed simulation is performed for the grid voltage fluctuations and line load rate which are normally caused by the change of PV power in real time environment.

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Effect of shadow for different configuration of PV System connected to Grid and model is discussed in [16]. Different PV array configuration was used on a three-phase two-stage system for deducing shadow effect on PV. Total cross Tied (TCT) was better than the SP configuration and the efficiency was increased approximately 4% in TCT configuration.

The Importance of cleaning of PV panels in desert environment for Grid-Connected PV Systems is shown in [17]. The efficiency of the PV system is analysed in dusty or desert climatic condition. This paper shows the effect of loss of energy generated by dust deposition on the solar panel.

In Paper [18] DIgSILENT/Power Factory is used for analysing the performance of Grid-connected PV System. Direct and indirect modelling using different PV models is done. In Direct modelling a detailed mathematical model is generated with analogous input and output characteristics This model suffers from a problem that the dynamic characteristics of internal system can not be studied. On the contrary the Indirect modelling combines the various components through a certain structure. The advantage of this method is that one can study I/P O/P as well as dynamic characteristics study.

In paper [19] the main emphasis is on the cost effective solution of single Phase grid Connected PV System. The paper focuses on different component used in grid connected PV system and the control part is not much considered for research. The new system designed has low cost and more efficiency.

In paper [20] simulation of PV- Battery system for in presence of grid for a local home is discussed. The controller works on Fuzzy Logic. In this paper optimization function is cost of electricity for house. The controller used which is Fuzzy Logic based works effectively to minimize the electricity cost of grid connected PV system having battery energy storage system.

The smart grid explained in the paper [21] integrates all the major components such as main grid, renewable energy generation, Battery system and load side management with the help of communication technology, control system and electronic sensors etc.

A Grid Connected PV system and a three-level control scheme of a single-phase power system is analysed in [22]. The maximum power point tracker is modelled in presence of irradiance and temperature variation. The voltage source inverter is able to maintain constant voltage and filter out ripples in output voltage of PV system. For this a simple PI control algorithm is used. The load is shared among PV and grid as the output from PV is varied due to environmental effects. System is also tested for different loading conditions and grid and PV both are analysed for amount of load shared.

The reactive power control in presence of PV is also a major challenge in the modern power system. Paper [23] address the above problem and envisage the solution. It also focuses to improve the voltage profile and the stability in grid connected PV system.

V. Conclusion

Solar Energy is a renewable energy source which has the potential to supply future electricity needs and hence great emphasis is being made now a days for increased usage in household as well as for commercial requirements. This paper reviews different techniques available on power quality problems for grid connected solar or PV cells. Power quality is not much deteriorated by issues like voltage sag, voltage swell in PV cells instead it is significantly adulterated due to issues like current harmonics, voltage harmonics. These also adversely affect the grid power quality when PV cells possessing lower quality power are being connected to the grid.

The remedies for the above issues are also reviewed in this paper and different analysis of the PV connected to Grid is also reviewed in this paper.

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