Role of FACTs Devices in 175 GW Large-Scale Renewable Energy Sources Integration into Indian Power Grid by 2022

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***Abstract*—** Renewable energy sources like solar and wind energy sources are intermittent characteristics in nature. Due to this intermittent characteristic, power output from solar PV and wind turbine generators are not constant. This variable power generation connected in the power grid causes the power quality problems such as voltage sag, swell, interruption, transients, under voltage and over voltage in the grid. These problems affect the performance of the equipment's in the utility as well as end user. The similar situation is experiencing in the Indian state of Tamilnadu. Tamilnadu is one of the renewable energy rich state identified by Govt of India (GoI) report of green corridor phase 1, having the installed capacity of wind more than 7600 MW and solar PV more than 1000 MW in January 2017. These wind turbines are installed near to the Western Ghats and the wind season is between the month of post May to post October in every year. Most of the installed wind turbine generators installed in Tamilnadu is type 1 and type 2 machines. These machines are requires reactive power support from the grid for their operation. When the cut in speed is not available at the tip of the turbine, Wind Turbine Generators (WTG) disconnected from the grid. During this time, reactive power drawl from the grid is reduced and voltage profile in the grid is increased. When the cut in speed is available at the tip of the turbine, wind turbine generators are connected to the grid. During this time, reactive power drawl from the grid is increased and voltage profile in the grid is reduced.

Some of the bus and transmission lines are experiencing under voltage and over voltage resulting to under and over voltage protection activated and tripping of these lines. The similar problem happening in TanTransco 400 kV grid in Tamilnadu. Tripping of 400 kV transmission lines leading to power outage in the particular transmission lines and it takes longer time to bring the transmission lines to active. Some extends it happened multiple times in a week. The GoI aiming to increase the installed capacity of renewable energy to 175 GW by 2022 with the contribution 60 GW WTG and 11900 MW from Tamilnadu. Enabling the higher renewable energy sources like large scale solar and wind into grid causes the power quality problems and these needs to be addressed for grid stability and reliability. FACTs devices are dynamic reactive power compensator capable of supplying of reactive power to the grid and consuming reactive power from the grid. This paper proposes the STATCOM a FACTs device is modelling in DIgSILENT power factory simulation software. STATCOM can able to supplying or consuming reactive power at the grid and it providing the ancillary services as mitigation of voltage sag, swell, momentary interruption, harmonics, under voltage and over voltage. This FACTs device enhancing the Indian power grid stability and reliability with 175 GW contribution from renewable sources contribution.

Keywords- Wind energy; STATCOM; power quality; renewable energy, DVR

I. INTRODUCTION

Power system comprises generation, transmission, distribution and utilization system. The overall installed capacity of India is 308.8 GW as on Nov 2016. Out of 308.8 GW, 219.78 GW from conventional sources, 43.1 GW from hydro power and 46.3 GW non-conventional sources. Large power system like Indian power system produce 219.78 GW power from conventional power. The non-conventional energy sources contributed by 28.2 GW of wind power, 8.7 GW of solar power, 4.3 GW of small hydro, 4.8 GW of bio power and 0.1 GW of waste to power connected across Indian power system [1]. The major problem associated with conventional power generation is scarcity of fossil fuels and environmental pollution. Transmitting the power from power plant to load center through long transmission lines cause the power loss. Distributed Generation (DG) is providing solution to transmission losses and voltage profile [10]. DG using Renewable Energy (RE) sources like solar, wind, biomass etc for distributed power generation. Solar and wind sources are mostly used for higher power generation. However intermittent characteristics and power electronics converter used for solar and wind power generation causes the Power Quality (PQ) problems in grid connected system [13]. These problems are voltage sag, swell, transients, harmonics, voltage flicker, under voltage, over voltage etc. The Government of India (GoI) is aiming to increase the renewable power to 175 GW power across Indian power system by the year of 2022 from identified renewable sources like solar, wind, small hydro and biomass [2]. Out of which 100 GW from solar (large scale, rooftop), 60 GW from wind, 5 GW from small hydro and 10 GW power from bio energy. This will significantly reduces the usage of coal and environmental pollution on the other hand it affects the grid power quality. IEEE standard 1159 – 2009, classified the power quality problems as short duration voltage variations (voltage sag, swell and interruption), long duration voltage variations (under voltage, over voltage and interruption), waveform distortion, transients

(impulsive and oscillatory), imbalance (voltage and current), voltage fluctuation and power frequency variations. PQ can be mitigate either from customer premises or utility side. Mitigating the PQ at customer premises is called as load conditioning and mitigating PQ at utility is called as line conditioning. Line conditioning devices counteracts or suppress the PQ disturbances and these device are super capacitors, flywheel energy storage, battery energy storage, isolation transformers, Transient Voltage Surge Suppressors (TVSS), noise filters and harmonic filters.

FACTs devices or custom power devices are providing the solutions to various power quality problems in the grid as well as end user. This paper discusses the various PQ problems associated with solar and wind power generation, role of FACTs devices to overcome the problems with high penetration of RE.

II. PQ PROBLEMS WITH THE GRID INTEGRATION OF RENEWABLES

A. Solar photovoltaic

The solar photovoltaic using the power electronic converter for their operation and integration. Power electronics in the converter introducing the power quality problem as harmonics, DC injection and voltage flicker. Output of a PV panels depends on solar light intensity, due to intermittent characteristics of solar irradiation (clouds) cause the variation in the output. That is cloud cover or shading effects leading to unstable in PV operation in grid connection.

B. Wind Turbine Generator

The characteristics of wind is intermittent in nature. Wind turbine could connect to the grid when velocity of the wind is above cut in speed and this could disconnect from the grid when wind velocity goes below the cut out speed.

There are four types of WTG namely type 1, type 2, type 3 and type 4. Type 1 and type 2 WTG are conventional type generator using Squirrel Cage Induction Generator (SCIG) and Wound Rotor Induction Generator (WRIG) respectively while type 3 and type 4 WTG are using the power electronics interface between the generator to grid. Type 1 and type 2 machines requires external reactive power support from grid or capacitor bank for their operation. Due to multiple connection and disconnection of these machine from grid leading to voltage sag, swell and transients in the grid. During the connection, it draws the reactive power from the grid create the voltage sag and disconnection from the grid create the swell. Switching of capacitor banks creates the transients. Type 3 and type 4 machines using the power electronics interface. These injecting the harmonics, DC injection into the grid and voltage flicker.

III. ROLE OF FACTS DEVICES IN PQ ENHANCEMENT

The concept of FACTs devices was introduced by N. G. Hingorani in 1995. FACTs devices is the combination of passive elements and active elements (power semiconductor devices) where the passive elements controlled by active elements. Based on type of compensation FACTs devices are broadly classified into two three namely shunt compensation, series compensation and hybrid compensation. Shunt compensating device are SVC and STATCOM, series compensating devices are DVR, TCSC and SSSC, hybrid device are UPFC and IPFC. Hybrid device is a combination of shunt and series compensating devices.

STATCOM used in distribution system is called as DSTATCOM. DSTATCOM is used to mitigate the harmonic distortion, load balancing, voltage regulation and improve the Power Factor (PF). It consist of voltage source PWM converter in connected in parallel with the supply and mitigate the current harmonics by injecting the current by 180° opposite phase shift. The shunt connected STATCOM is shown in figure 1.

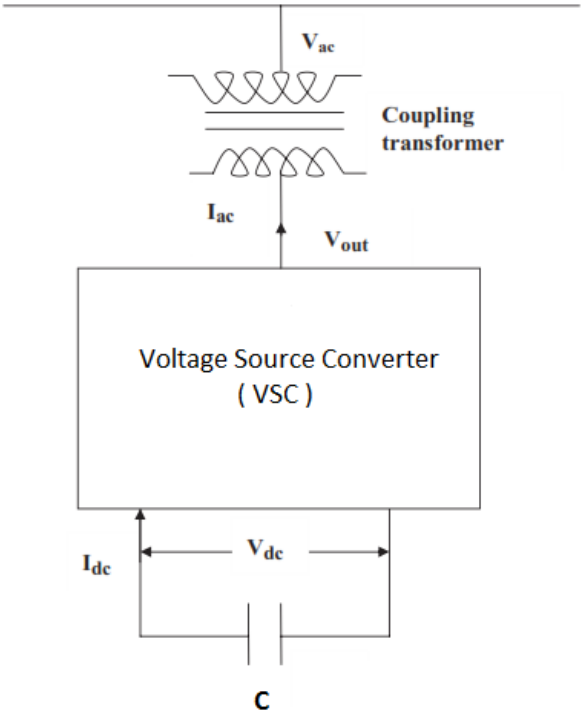

Figure 1: Schematic diagram of STATCOM

A STATCOM is a controlled reactive power source and it providing dynamically varying reactive power control by absorbing or supplying the reactive power. The concept of reactive power exchange (supplying or absorbing) is shown in figure 2.

The reactive power exchange between the VSC and AC system is controlled by varying the output voltage (Vout). If converter output voltage Vout is greater than utility bus voltage Vac , reactive power (capacitive) is supplying to the grid. If utility bus voltage Vac is greater than converter output voltage Vout, converter absorbs the reactive power (inductive) from the grid.

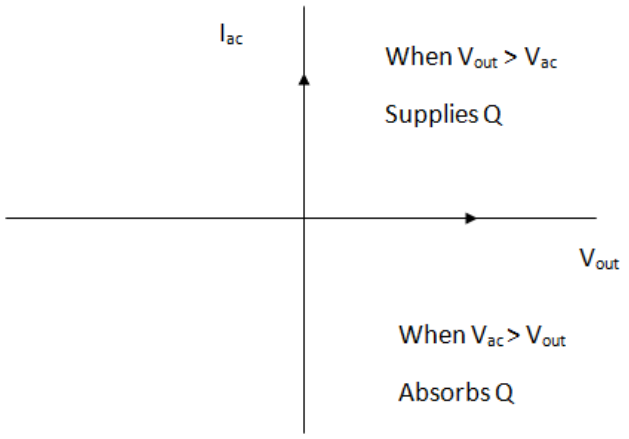

Figure 2: Reactive power exchange of STATCOM

Dynamic Voltage Restore (DVR) is a series connected device used for protecting the loads from supply voltage disturbances in distribution system. The schematic connected DVR is shown in figure 3. It consists of injection transformer, harmonic filter, Voltage Source Converter (VSC) and control system. PWM based VSC with DC capacitor connected in series with utility voltage supply and coupling transformer.

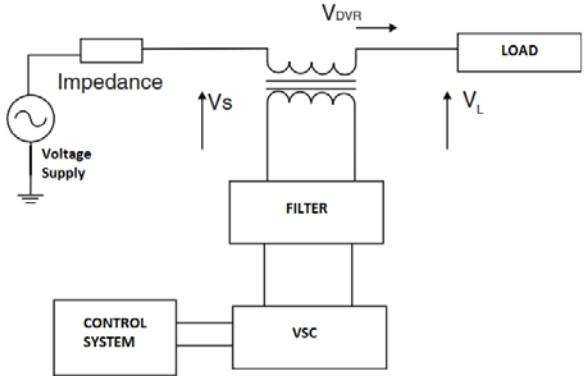

Figure 3: Schematic diagram of DVR

The DVR is act as a series filter and isolating the harmonics injected by the loads. DVR is similar to Static Synchronous Series Compensator (SSSC).

Unified Power Quality Conditioner (UPFC) is a combination of shunt and series connected devices in back to back connection share a common DC capacitor. The shunt part of the UPFC is responsible for mitigate current quality issues caused by connected loads as current harmonics, load balancing and poor PF etc while series part of the UPFC responsible for voltage issues as voltage sag, swell, harmonics, flicker and unbalance . UPFC is more suitable for improve the power quality to large capacity loads. I The UPFC is shown in figure 4.

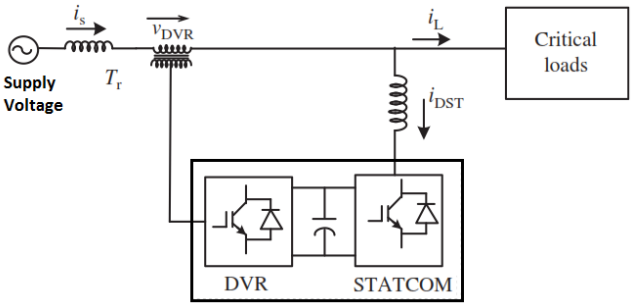

Figure 4: Schematic diagram of UPFC

IV. Power Quality Enhancement using STATCOM

STATCOM is a shunt connected FACTs device capable of supplying or absorbing the dynamically varying reactive power compensation from the grid. During lightly loaded condition / highly loaded condition STATCOM reduces the overvoltage/under voltage and maintain the voltage regulation. It mitigates the voltage sag, swell, momentary interruption, harmonics, under voltage and over voltage of the grid. The application of STATCOM in wind power enhance the transients, flicker mitigation etc [4].

V. Conclusion

This paper discusses the role of FACTs devices for PQ enhancement.

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