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Evaluation of Voltage Stability in a Microgrid with STATCOM

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Abstract*— Increasing concerns regarding global warming caused by greenhouse gases, which are mainly generated by conventional energy resources, e.g., fossil fuels, have created significant interest for the research and development in the field of renewable energies. Such interests are also intensified by the finitude availability of conventional energy resources. To take full benefit of renewable energy resources, e.g., wind and solar energy, interfacing power electronics devices are essential, which together with the energy resources formDistributed Generation (DG) units. If properly controlled and coordinated, the optimal and efficient operation of DG units, which are the main building block of rapidly emerging microgrid technologies, can be ensured. In fact, the optimal and efficient operation of any energy conversion systems, e.g., microgrids, traction networks, etc., necessitates some sorts of control strategies. Being structured into two main parts and exploiting two-level Voltage Source Converters (VSCs), this article introduces a control strategy in the context of microgrids and electrified traction networks.

***Keywords*— microgrid, wind turbine, Photovoltaic, STATCOM**

I. INTRODUCTION

Microgrid, which is formed by grouping a cluster of distributed energy resources, storage devices and controllable loads in a common local area, has attracted widespread attentions [1]. The control strategy in both the grid connected and islanding modes of a microgrid can be found in literature [2]. A microgrid is defined as a part of an electric power distribution network that embeds an appreciable number of distributed generators and energy storage devices, in addition to regional loads; it may be disconnected from the rest of the power system, under emergency conditions or as planned, and operated as an island. A microgrid can be a residential neighborhood, an industrial or commercial facility, a university campus, a hospital, an off-grid remote community, etc. Micrograds should widely utilize renewable energy resources such as wind, sunlight, and hydrogen1, to play a significant role in the electric power systems of the future, for cleaner air, reduced transmission and distribution costs, and enablement of energy efficiency enhancement initiatives. The economical and environmental benefits of microgrids have motivated extensive research and development efforts towards resolving the technical challenges of this new and fast growing technology[3].

II. MICROGRID

The microgrid concept assumes a cluster of loads and microsources operating as a single controllable system that provides power to its local area [4, 5]. Microgrids offer solutions to implementing distributed energy resources such as diesel generators, wind turbines, photovoltaic cells etc. at or near the point of load. This decreases the stress on the electrical transmission system and offers a significant increase in power system reliability as power can be generated locally. From a grid perspective, the microgrid concept is attractive because it recognizes the reality that the traditional grid structure is old and has to change[4]. Microgrids may or may not be connected to the main distribution grid that is maintained and operated by the distribution network operators. Microgrids can also provide premium power through the ability to smoothly move from dispatched power mode while connected to the main utility grid to load tracking while in island mode [5]. The microgrid concept is made possible by the recent advances in reliable small scale generators, power electronics and digital controllers. The majority of the present day microsources are power electronics based. As a result, they can provide the required flexibility to ensure controlled operation as a single system.

A basic microgrid architecture is shown in Figure 1. This microgrid consist of diffrent DGs and a collection of loads.

Figure 1: Microgrid Structure

A. Wind turbine

Wind turbines are packaged systems that include a rotor, a generator, turbine blades, and a drive or a coupling device. As wind blows through the blades, the air exerts aerodynamic forces that cause the blades to turn the rotor. As the rotor turns, its speed is altered to match the operating speed of the generator. Most systems have a gearbox and a generator in a single unit behind the turbine blades. As with photovoltaic (PV) systems, the output of most wind generators is processed by an inverter that changes the electricity from DC to AC so that the electricity can be used.

A wind turbine operates by extracting kinetic energy from the wind passing through its rotor. The power developed by a wind turbine is given by [6]:

$$P_{\omega} = 0.5 \rho A V^{3} \tag{1}$$

Where

P power (W),
Cp power coefficient,
Vw Wind velocity (m/s),
A swept area of rotor disc(m2),
density of air (1.225 kg=m3).

The force extracted on the rotor is proportional to the square of the wind speed and so the wind turbine must be designed to withstand large forces during storms. Most of the modern designs are three-bladed horizontal-axis rotors as this gives a good value of peak Cp together with an aesthetically pleasing design [7].

The power coefficient Cp is a measure of how much of energy in the wind is extracted by the turbine. It varies with the rotor design and the relative speed of the rotor and wind (known as the tip speed ratio) to give a maximum practical value of approximately 0.4 [7]. The power coefficient Cp is a function of the tip speed ratio, and the pitch angle , whichwill be investigated further. The calculation of the performance coefficient requires the use of blade element theory [8]. As this needs knowledge of aerodynamics and the computations are rather complicated, numerical approximations have been developed [8]. Here the following function will be used:

$$C_P(\lambda,\beta) = c_1\left(\frac{c_2}{\lambda_i} - c_3\beta - c_4\right)e^{\frac{-c_5}{\lambda_i}} + c_6\lambda \tag{2}$$

$$\frac{1}{\lambda i} = \frac{1}{\lambda + 0.008} - \frac{0.035}{\beta^{3} + 1} \tag{3}$$

Figure 2 shows Cp(λ, θ) versus λ characteristics for various values of β. Using the actual values of the wind and rotor speed, which determine λ, and the pitch angle, the mechanical power extracted from the wind can be calculated from equations (2)-(3). The maximum value of Cp (cpmax=0.48) is achieved for β = 0 and for λ = 8.1. This particular value of λ is defined as the nominal value (λ nom).

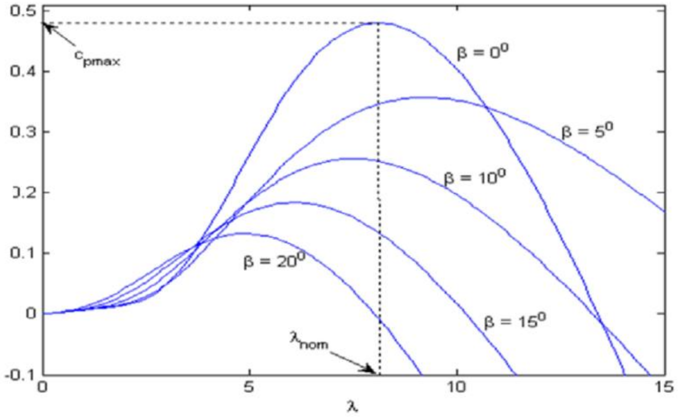

Figure 2: Performance coefficient Cp as a function of the tip speed ratio λ with pitch angel β as a parameter.

The working principles of the wind turbine can be described in two processes, that are carried out by its main components: the rotor which extracts kinetic energy from the wind passing it and converts it into mechanical torque and the generating system, which converts this torque into electricity. Figure 2 illustrates the working principles of a wind turbine.

Basically, a wind turbine can be equipped with any type of a three phase generator. Several generator types may be used in wind turbines, but here three types of wind turbine generators are discussed: Squirrel cage induction generators, Doubly fed induction generators, Direct drive synchronous generators, that in this article Squirrel cage induction generators is the base wind turbine for simulations.

B. Photovoltaic

The photovoltaics (PVs) are an attractive source of renewable energy for distributed urban power generation due to their relatively small size and noiseless operation. Their applications are expected to significantly increase all over the world. PV generating technologies have the advantage that more units can be added to meet the load increase demand [9]. Photovoltaic cells can be divided into four groups: crystalline cells, thin-film cells, dyesensitised solar cells and multilayer cells. The latter can also be considered as several layers of thin-film PV cells. The different types are described in [10]. An initial understanding of the performance of a solar cell may be obtained by considering it as a diode. The light energy, which is in the form of photons with the appropriate energy level, falls on the cell and generates electron-hole pairs. The electrons and holes are separated by the electric field established at the junction of the diode and are then driven around an external circuit by this junction potential. There are losses associated with the series and shunt resistance of the cell as well as leakage of some of the current back across the p-n junction[11]. This leads to the equivalent circuit shown in Figure 3.

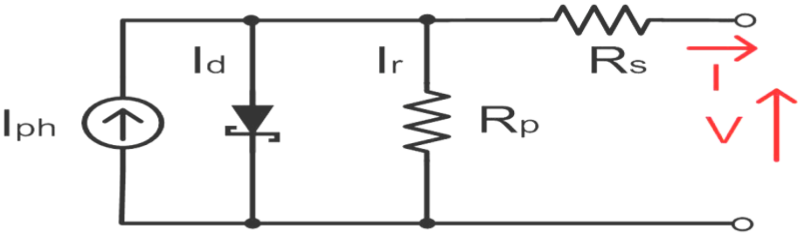

Figure 3: The circuit of Photovoltaic cell

The photo current (Iph) is a function of the solar irradiation. A series resistor Rs and a parallel resistor represent respectively the voltage loss and the leakage current of the cell. The diode D characterises the non linear behavior of the cell and the dependency of its performance on ambient temperature.

C. Diesel Engine

Diesel Engines, developed more than 100 years ago, were the first among distribution generator technologies. Because of their high efficiency and reliability they are used on many scales, ranging from small units of 1 KW to large several tens of MW power plants. Smaller engines are primarily designed for transportation and can usually be converted to power generation with little modification. Large engines are most frequently designed for power generation, mechanical drives, or marine propulsion. Because of sudden changes in load demands by the consumers, it is important that the diesel prime mover has a fast dynamic response and good capabilities of isturbance rejection.

D. STATCOM

STATCOM is a member of the Flexible AC transmission systems (FACTS) family that is connected in shunt with ac power systems. STATCOM has played an important role in the power industry since the 1980s. STATCOM provides many advantages, in particular the fast response time and superior voltage support capability. STATCOM is used for dynamic voltage control to suppress short term voltage fluctuations because its dynamic performance far exceeds other var compensators [12-15].

III. RESULTS AND DISCUSSION

The performance of the proposed controller in micro grid is demonstrated with system normal condition(without fault) and under one-phase and three phasefault. Simulation waveforms for the entire three micro sources are presented in Figures 4.

STATCOM is a DC-AC voltage source converter with an energy storage unit, usually a DC capacitor. Power electronic switches are used to derive an approximately sinusoidal output voltage from a DC source. The power circuit diagram of a VSC-based STATCOM is illustrated in Figure 4 where six IGBTs with its anti- parallel diodes and a DC-link capacitor are used to produce the three-phase voltage. The STATCOM is coupled to the ac power grid via coupling inductors Lc. The coupling inductors are also used to filter out the current harmonic components that are generated by the pulsating output voltage of the power converter.

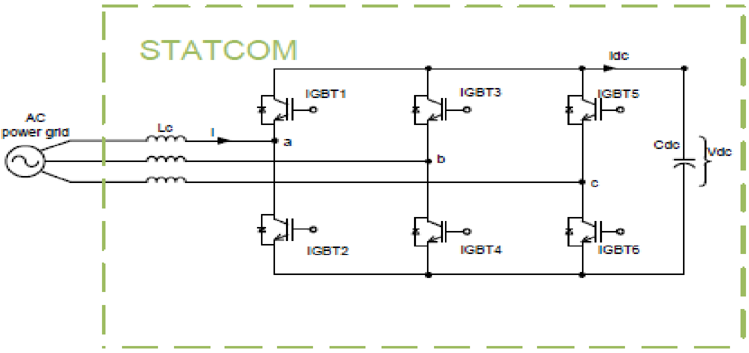

Figure 4: Power circuit diagram of a STATCOM

The exchange of active and reactive power between the STATCOM and the ac power grid can be controlled by adjusting the phase and amplitude of the converter output voltage. STATCOM can be operated in the capacitive mode (inject reactive power) by controlling the amplitude of the converter voltage to be greater ac power grid voltage. In contrast, the magnitude of the converter voltage is controlled to be less than that of the ac power grid voltage in order to absorb reactive power or operate the STATCOM in the inductive mode. The converter operation is associated with internal losses caused by non-ideal power semiconductor devices and passive components. Without any proper control, the capacitor voltage will be discharged to compensate for these losses. The capacitor voltage is regulated by introducing a small phase shift between the converter voltage and the ac power grid voltage.

IV. RESULT

The power system in a State of persistent work in balance between production and consumption to take over, and if the balance of the event stir welding between the nominal value of the microgrid parameters go, will go away. This article is for voltage control and other parameters of the microgrid is used. If not, the control system of the swing can be a lot of damage, even to a production unit shutdown also happens. The output be and other parameters are also two modes of presence and absence of DSTATCOM have been analyzed.

The following changes to the overall voltage shows a microgrid. The first case related to the presence of the second mode and without the presence of DSTATCOM shown in Figure 5,6.

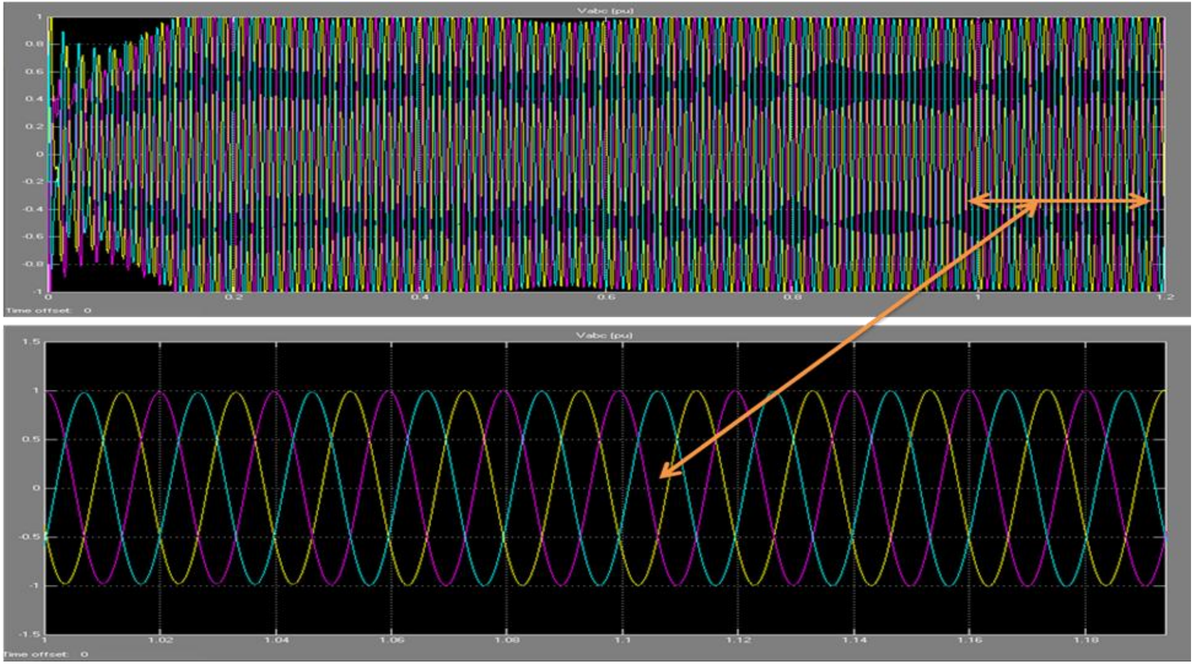

Figure 5: Microgrid effective voltage in the presence of DSTATCOM

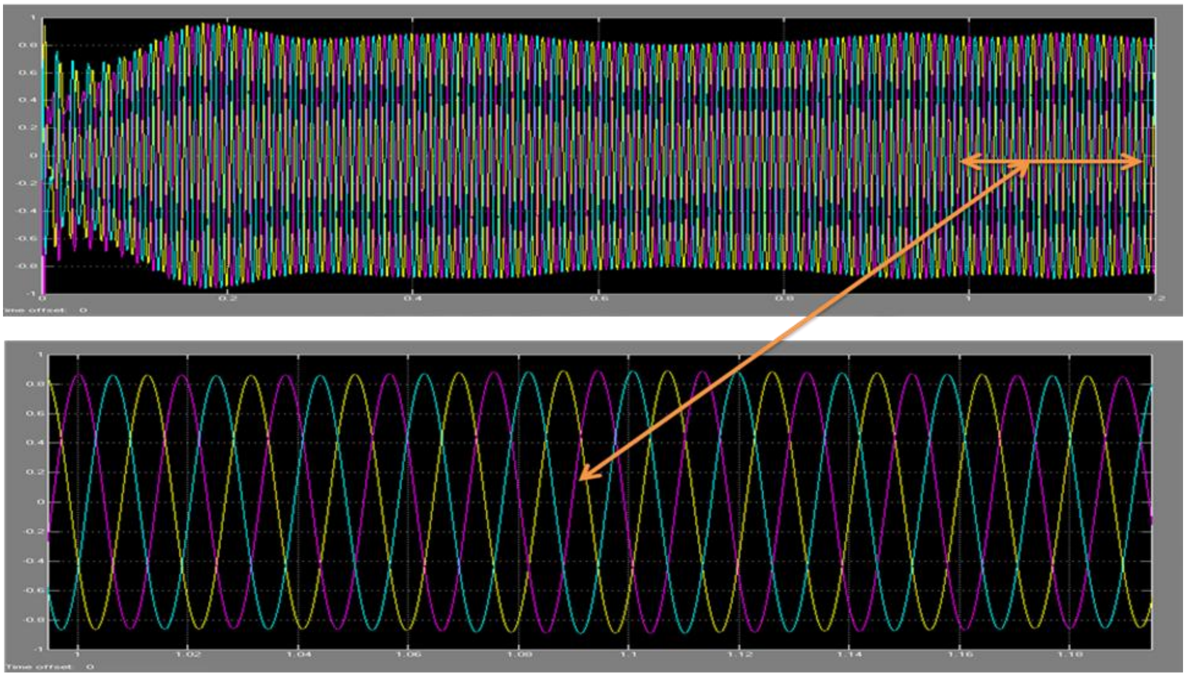

Figure 6: Microgrid effective voltage in The absence of DSTATCOM

The Compensator DSTATCOM connected in parallel to the power grid and can be fitted as a reactive power of the load the network capture and Salafi or capacitive reactive power as once the injection to the network. If the DC voltage source with a DSTATCOM fan is able to be active to be injected into the network. This compensation mechanism as well as improving sustainability in the SVC power system voltage regulation, power factor correction and power control is reactive.

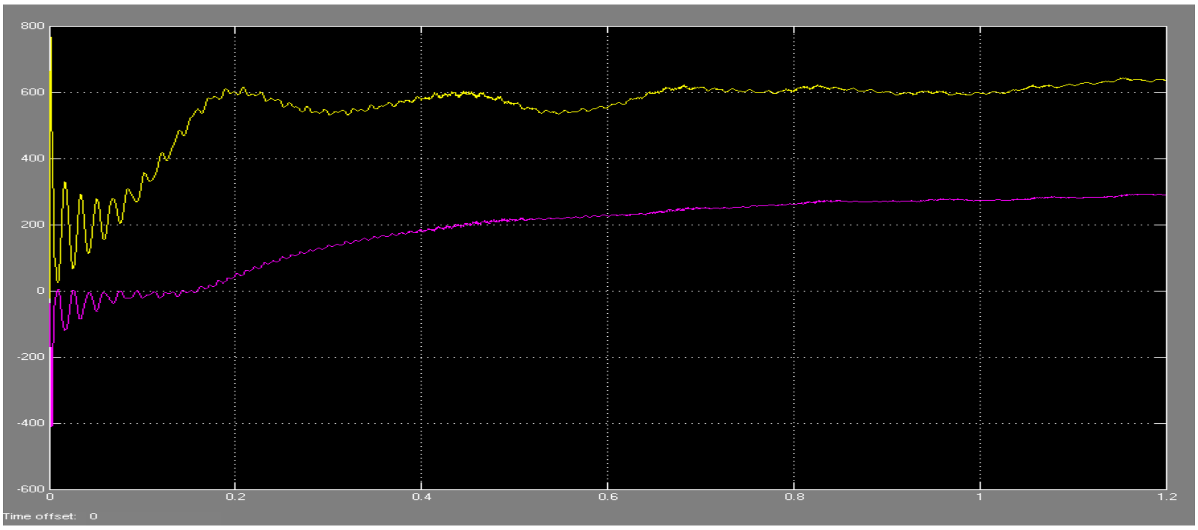

Figure 7: Active an Reactive power in the presence of DSTATCOM

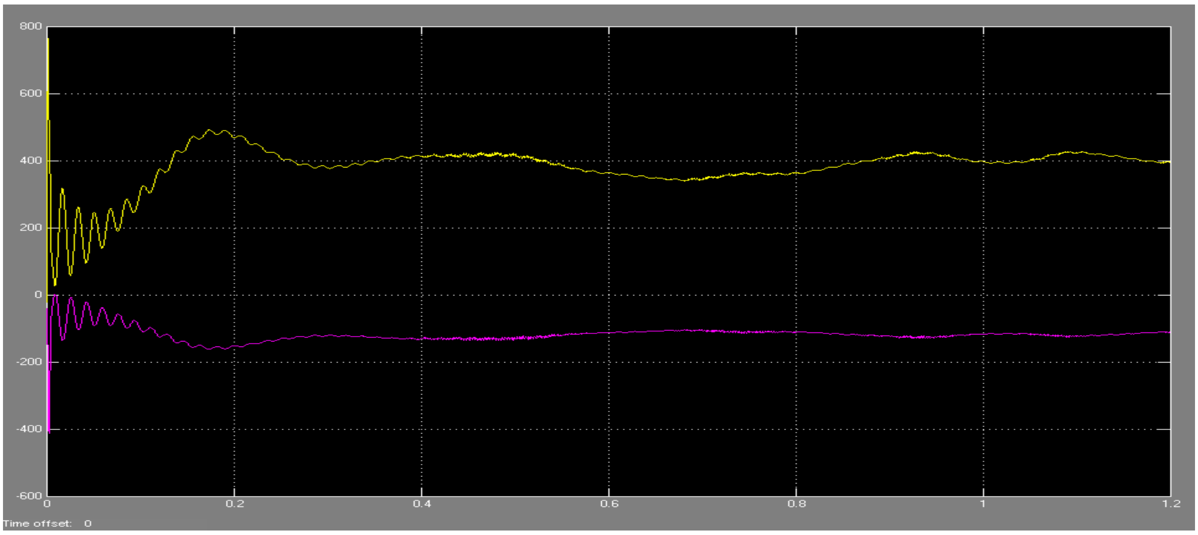

Figure 8: Active an Reactive power in The absence of DSTATCOM

Figure 7 the active and reactive power injection in the presence of DSTATCOM and Figure 8 active and reactive power injection in the absence of a showing of DSTATCOM. As mentioned in the previous section as well as in other instruments of DSTATCOM can play an role in improving the quality of be have.

V. CONCLUSIONS

A simulation study highlighting the real and reactive power capabilities of the STATCOM has been explained in detail. The simulation study verified that the STATCOM with SCESS can rapidly absorb/inject stored energy from/to the grid. The real power capabilities of the STATCOM can be employed in power burst application such as voltage stabilization studies where rapid discharge of stored energy is required to compensate for voltage variation due to the slow response of generators.

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