IMPROVING GRID TRANSIENT STABILITY THROUGH STATCOM WITH EV BATTERY AS ENERGY STORAGE SYSTEM

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Abstract—The increase in electricity cost and unavailability of electricity to EV users will be a major problem in the future scenario where number of EVs will increase on road. Intelligent charging technologies can facilitate hassle-free integration of EVs to the grid. Integration of STATCOM with energy storage devices (EV battery) can play an important role in improving the voltage stability at the bus where EVs are connected. This paper proposes a system that demonstrates how the integration through STATCOM with the supply utility can significantly improve the exchange of both active and reactive power with the utility through the bus to which EVs are connected.

Keywords—STATCOM, Transient stability, Electric vehicles, Battery, Energy Storage System

I. INTRODUCTION

STATCOMs are capable of providing both inductance and capacitance used in voltage support and provide active and reactive power independently. The STATCOM can provide both active and reactive power to the grid. It is connected through a transformer to the grid.

The STATCOM can quickly draw excess energy available in the grid and transfer it to the battery of the EV or transfer energy from the battery to the grid to improve transient stability. The STATCOM can quickly draw excess energy available in the grid and transfer it to the battery of the EV or transfer energy from the battery to the grid to improve transient stability. Voltage control can be accomplished by the use of battery as energy storage system. [1]

This paper presents a study on improving transient stability through the STATCOM model in MATLAB/SIMULINK. Depending upon the short-circuit impedance at the bus where EVs are connected, the maximum power that can be drawn will get limited. In conventional AC systems, the ability to transfer power is limited by many factors such as thermal limits, voltage limits, transient stability limit, short circuit limit etc. These limits defined the maximum power that can be efficiently transmitted through transmission lines without causing any damage to the electrical equipment and transmission lines. The solution proposed to solve these problems consists of connecting a STATCOM to the point of common connection i.e., the power system to where the load is connected. [3] It is proposed that by introducing a STATCOM between the EVs and the load bus, the voltage stability and the maximum power that can be drawn from the utility can be improved. To achieve this, analysis is done using N-R load flow method and it is shown how the voltage stability is improved resulting in the maximum power that can be drawn from the utility. The results show that integration of EV through STATCOM with the supply utility can significantly improve the exchange of both active and reactive power with the utility through the bus to which EVs are connected and the voltage stability of the system to which EV is connected.

II. METHODOLOGY

In conventional AC systems, the ability to transfer power is limited by many factors such as thermal limits, voltage limit, transient stability limit, short circuit limit, etc. These limits define the maximum power that can be efficiently transmitted through transmission line without causing any damage to the electrical equipment and transmission lines.

The system provided with STATCOM can enhance the controllability and stability of the transmission system with an increase in power transfer capability of the system. The basic operating principle of STATCOM is reactive power generation by a voltage sourced converter which is similar to conventional rotating synchronous machine is shown schematically, in the form of a single-line diagram in the figure below

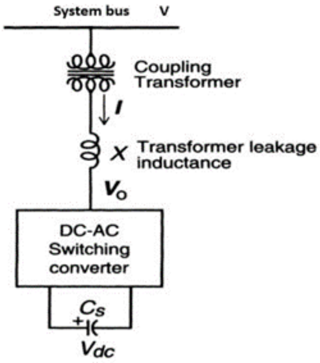

Fig1.Single line diagram of STATCOM

From a DC input voltage source, provided by the charged capacitor Cs, the converter produces a set of controllable three-phase output voltages with the frequency of the ac power system. Each output voltage is in phase with, and coupled to the corresponding ac system voltage via a relatively small (0.1-0.15 P.U.) tie reactance (which in practice is provided by the per phase leakage inductance of the coupling transformer). By varying the amplitude of the output voltages produced, the reactive power exchange between the converter and the ac system can be controlled in a manner similar to that of the rotating synchronous machine. That is, if the amplitude of the output voltage is increased abov that of the ac system voltage, then the current flows through the transformer inductance from the converter to the ac system, and the converter generates reactive (capacitive mode) power for the ac system. If the amplitude of the output voltage is decreased below that of the ac system, then the reactive current flows from the ac system to the converter, and the converter absorbs reactive (inductive mode) power. If the amplitude of the output voltage is equal to that of the ac system voltage, the reactive power exchange is zero.

The figure below shows the three phase six pulse bridge converter. The three-phase output voltage is generated by a voltage-sourced dc to ac converter operated from an energy storage capacitor. The converter establishes a circulating current flow among the phases with zero net instantaneous power exchange for which the dc storage capacitor is needed. In a practical converter, the semiconductor switches are not lossless, and therefore the energy stored in the dc capacitor would be used up by the internal losses. By equipping the converter with a dc source like a battery, the switching losses can be accounted for and the converter can control both reactive and real power exchange with the ac system, and thus it can function as a static synchronous generator.

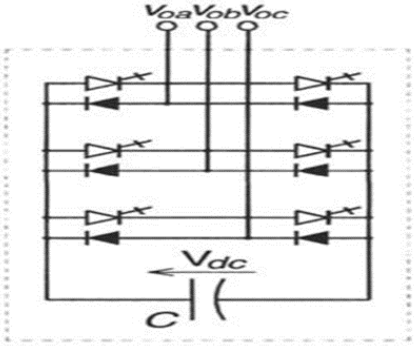

Fig.2. Three phase 6-pulse bridge converter

Control schemes- 1. Internal control

The figure 3 shows the internal control of the STATCOM which is an integral part of the converter. Its main function is to operate the converter power switches to generate a fundamental output voltage waveform with the demanded magnitude and phase angle in synchronism with the ac system.

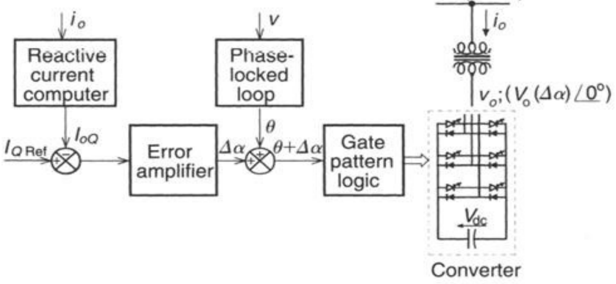

Fig.3.Internal control of STATCOM

The inputs to the internal control are: the ac system bus voltage, v, the output current of the converter, io and the reactive current reference, IQRef Voltage v operates a phase- locked loop that provides the basic synchronizing signal, angle θ. The output current, I0 is decomposed "into its reactive and real components, and the magnitude of the reactive current component, IQ , is compared to the reactive current reference, IQRef The error thus obtained provides, after suitable amplification, angle α, which defines the necessary phase shift between the output voltage of the converter and the ac system voltage needed for charging (or discharging) the storage capacitor to the de voltage level required. Accordingly, angle a is summed to (α) to provide angle (θ+ α), which represents the desired synchronizing signal for the converter to satisfy the reactive current reference. Angle (θ+ α), operates the gate pattern logic (which may be a digital look-up table) that provides the individual gate drive logic signals to operate the converter power switches. [4]

2. External control

In order to meet the general compensation requirements of the power system, the output of the static var generator is to be controlled to maintain or vary the voltage at the point of connection to the transmission system shown in the figure below.

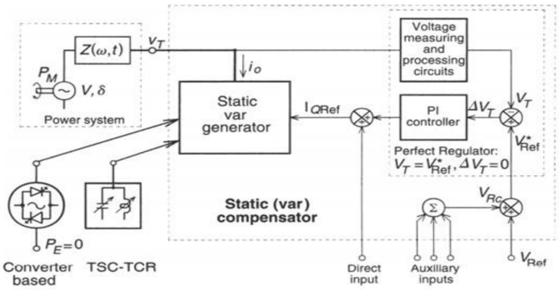

Fig.4.External control of STATCOM

The output of the static var generator is controlled so that the amplitude I0 of the reactive current i0 drawn from the power system follows the current reference IQRef With the basic static compensator control, the var generator is operated as a perfect terminal voltage regulator: the amplitude VT of the terminal voltage VT is measured and compared with the voltage reference VRef, the error ΔVT is processed and amplified by a PI (Proportional Integral) controller to provide the current reference IQRef for the var generator. In other words, IO is closed-loop controlled via IQRef so that VT is maintained precisely at the level of the reference voltage VRef in case of power system and load changes. [4]

A. Two bus system study model

The model assumed in this paper is shown in Fig.5, a two-bus system simulated in MATLAB Simulink.

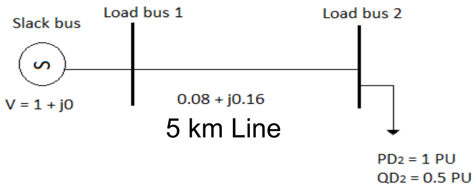

Fig. 5. Two bus system model

The STATCOM is introduced in the following two bus system as shown in Fig. 6. The introduction of STATCOM is expected to improve voltage stability.

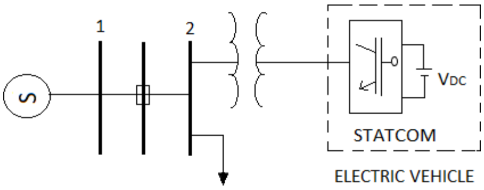

Fig. 6. Two bus with STATCOM model

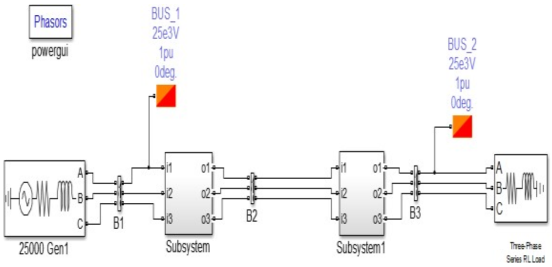

Fig.7. Simulink block diagram of system without STATCOM

Load flow of the system was conducted and different values of PD2 and QD2 were obtained keeping the power factor constant and the results were obtained by following the graph

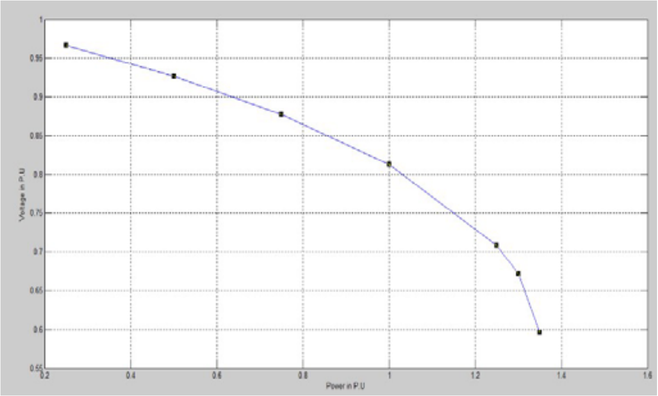

Fig. 8. Two buses without STATCOM graph

B. Simulation with STATCOM

A STATCOM is introduced in the 2-bus system and it is expected to improve the voltage stability. The voltage at load bus is obtained for three different values, when STATCOM is injecting no reactive power to the load bus, is injecting reactive power which is 50% of the reactive power of load, and when STATCOM is injecting reactive power which is 100% of the reactive power of load and following graph was obtained after the load flow study.

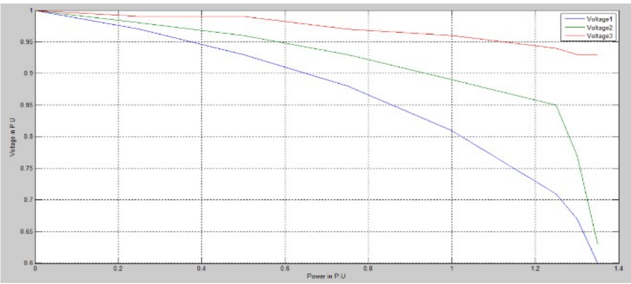

Fig. 9. Two buses with STATCOM model graph

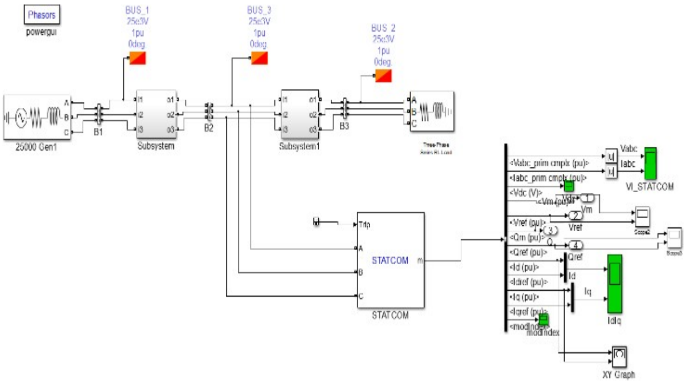

Fig 10. Simulink block diagram with STATCOM

Bus 3 is created at the output of STATCOM. Bus 3 is considered as a PV bus whose magnitude is specified as V = 1.0 p u. and the active power is specified as 0.0 p u. and load flow is performed.

1. SIMULINK BLOCK DIAGRAM WITH STATCOM AND 3 PHASE FAULT

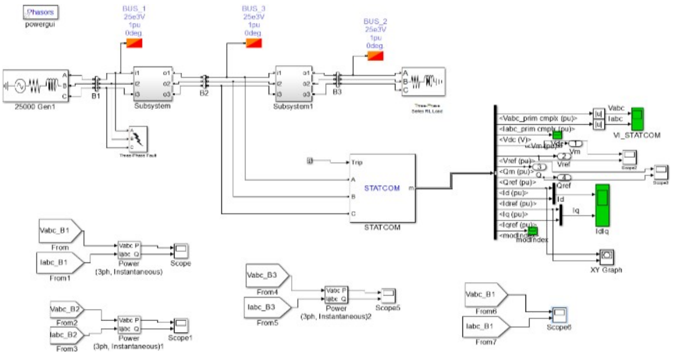

Fig. 11. Simulation block diagram with STATCOM and fault

The above simulation was carried out and fault and load flow studies were done. The following graphs were obtained.

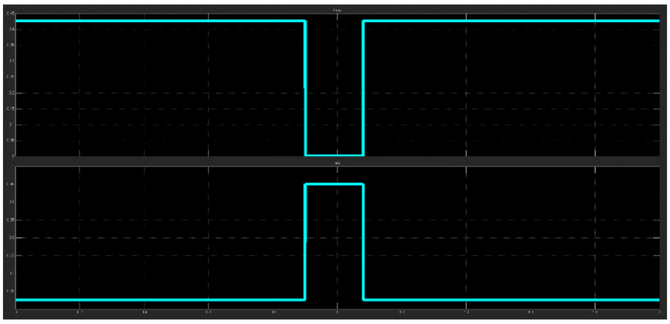

Fig.12.V, I Graph of system with STATCOM during fault

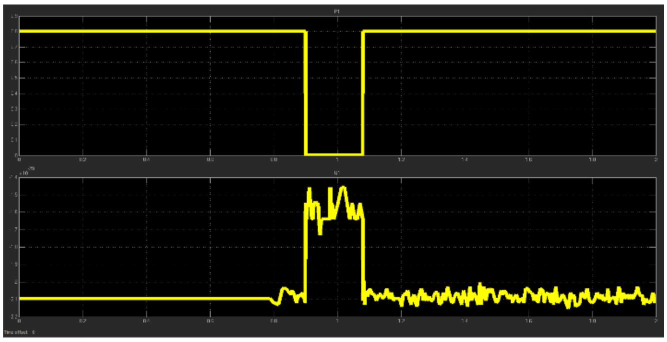

Fig.13. Active and Reactive power during fault period

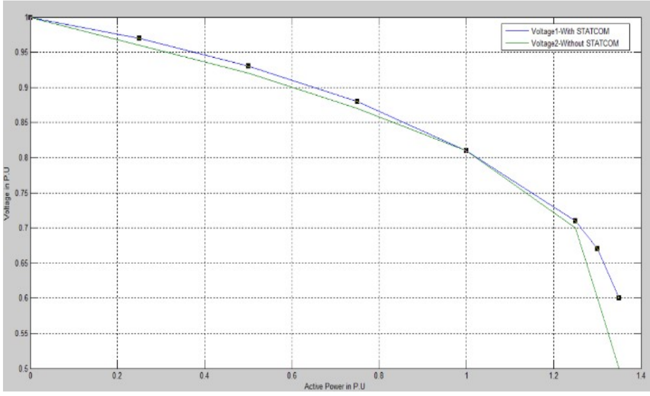

Fig.14. Comparison of P Vs. V Graph of system with STATCOM and without STATCOM

III. SIMULATION RESULTS

The results for the system connected to the load without STATCOM in fig.7 shows that with the increase in active power drawn by the load, the Voltage at bus 2 decreases. By increasing PD2 in small steps it was found out that 1.35+j0.67 P.U is the maximum power that can be transmitted.

The results for the system connected to the load with STATCOM in the system in fig.8 shows that with the increase in active power drawn by the load, the Voltage at bus 2 decreases in very small steps. With the increase in reactive power supplied by the STATCOM, the Voltage stability increases significantly.

The results for the system connected with a 3-Phase unsymmetrical fault and STATCOM in fig.13 shows that the voltage stability of the system improves and that STATCOM can provide reactive power support even during fault period.

IV. CONCLUSION

From the simulation it is inferred that the introduction of STATCOM in the system improves the voltage stability and the maximum power that can be drawn from the utility is improved significantly. The STATCOM has little active power providing capability. This can be improved by adding EV as Energy Storage System.

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DATA CENTER INFRASTRUCTURE AND POWER CONSUMPTION

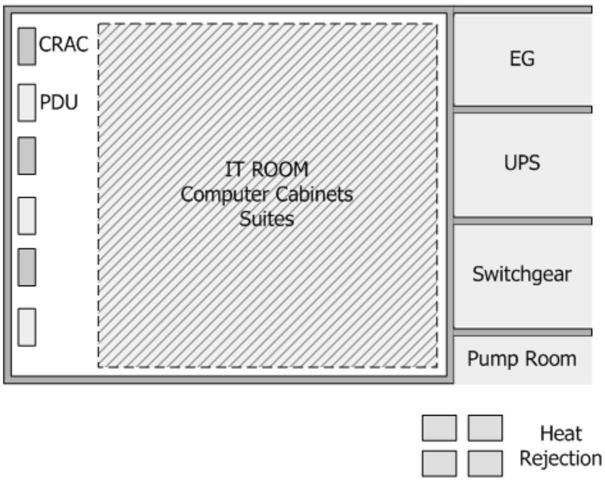

Figure 2.1. Typical Data Center Infrastructure [18, 19]

The overall design of a data center can be classified in 4 categories Tier I-IV each one presenting advantages and disadvantages related to power consumption and availability [18, 19]. In most cases availability and safety issues yield to redundant N+1, N+2 or 2N data center designs and this has a serious effect on power consumption. According to Figure 2.1, a data center has the following main units

1.1. Power Consumption in Data Centers

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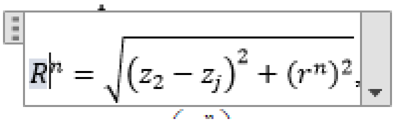

$$R^{n} = \sqrt{\left(z_2 - z_j\right)^2 + (r^{n})^2} \tag{2.1}$$

The optimal description of this value depends on the system’s characteristics and the type of equipment. As an example, for modulation and coding techniques in wireless communications the spectral efficiency is a common measure. For electronic components the ratio of joule per bit best describes performance. In telecommunication networks and datacenters the ratio of watts consumed over the Gbps of data processed is preferred. In [22] an absolute energy efficiency metric is introduced, named as dBε.

2. CONCLUSION

A concise summary of the findings and a clear identification of the advance/contribution that this work provides to the field.

3. ACKNOWLEGDEMENTS

4. FIGURES AND TABLES CAPTION LIST

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