Mitigation of Voltage Sag in Distribution Line using 6 Pulse D-STATCOM

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***Abstract*—During the ongoing growth of technologies, it's increasing the power of load demand. These requires system stability and reliability during distribution power to the load. In this paper, study on operation and control of the distribution STATCOM (D-STATCOM) is done. It helps in the better utilization of a network operation under normal and voltage sags condition. This research is proposed by using PSCAD/EMTDC software. Design of 6-pulse D-STATCOM is analyzed and simulated, thus shows its effectiveness in mitigating voltage sags.**

***Index Terms*—6 Pulse D-STATCOM; PSCAD; Voltage Sag.**

I. Introduction

Flexible AC transmission systems or known as FACTs devices help to control power flow on overloaded lines, which then result in better laudability of power system, reduce transmission line losses, improve line stability and security, and make the transmission system more energy-efficient. Other than using FACTs, improvement of power flow can be achieved by controlling the inverters using suitable controllers [1, 2]. In order to find suitable FACTS locations easier, this paper presents a graphical user interface (GUI) based on a genetic algorithm (GA) that able to find the ideal locations of multi-type FACTS devices in large power systems [3]. Five different FACTS devices that commonly implemented are; the Static Var Compensators (SVCs), the distribution Static Synchronous Compensators (D-STATCOMs), the Thyristor Controlled Series Compensators (TCSCs), the Static Synchronous Series Compensators (SSSCs), and the Unified Power Flow Controllers (UPFCs). In this paper, the D-STATCOM is the main interest.

D-STATCOM is the static counterpart of the rotating synchronous condenser and therefore, it generates and absorbs reactive power faster [4]. In principle, the voltage regulation function is as same as when connected in series, but performs better because the operation is not dependent with low voltage presence. At the fundamental frequency, D-STATCOM generates a balanced set of three phase sinusoidal voltages. With the use of controller, it can produce rapidly controllable amplitude and phase angle [5]. There are several papers that have been published mentioned on the effectiveness of D-STATCOM to improve power quality especially voltage sags [6-9]. As voltage sag is one of the most occurring power quality problems, this research aims to mitigate voltage sags using D-STATCOM.

II. Methodology

A distribution line had a line-to-line voltage, 11kV is assumed loaded with IMVA load at 0.9 power factor lagging had been design. The voltage source will act as secondary part of the transformer and is directly connected to the three-phase wye-connected load.

Second step was to insert all the data obtained to PSCAD / EMTDC software. In this step, the suitable circuit as in figure 1 without using D-STATCOM is designed and analyzed. In this system, an 11kV, 50 Hz and 15MVA AC source and 1MVA load with 0.9 lagging power factor for each single phase are used. The load impedance value for R and L is 36.3Ω and 0.05596H respectively. These values were obtained based on calculation using the given parameters above. The result from the simulation is then compared between theory and after analyzing using PSCAD.

Third step is designed the circuit using 6-pulse D-STATCOM as in Figure 2 and then analysed using PSCAD. The transformer that been use is the step down transformer and it connected in shunt between STATCOM and the transmission system. The value of step down transformer that been used in this simulation are 11/2 kV for Y-Y configuration and 11/3.414kV for Y-delta connection. Transformer T1 are Y-Y transformer, T2 is Y-delta configuration. GTO for power electronic devices electronics devices that are used in simulation is been selected because it capability of turn off and GTO that can be turned on by applying a positive gate signal and GTO rapidly turns off and recovers to withstand the forward the forward voltage and be ready for the next turn-on pulse.

Figure 3 shows the simulation graph when no fault occurred. Result are then compared between theory and after analyzing using PSCAD.

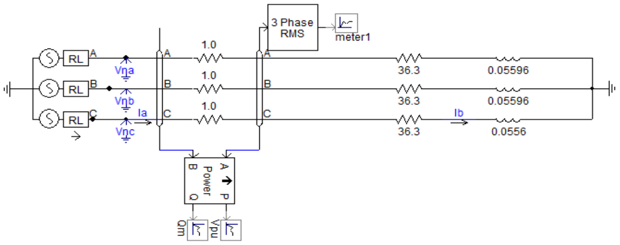

Figure 1: Distribution system with load

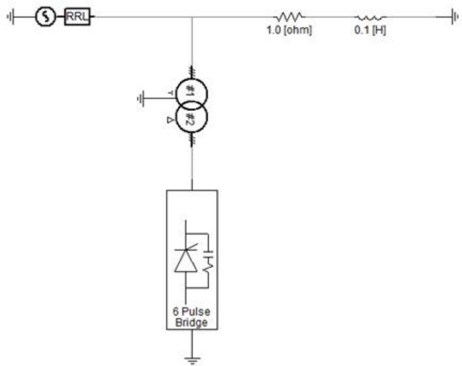

Figure 2: Schematic Diagram of D-STATCOM

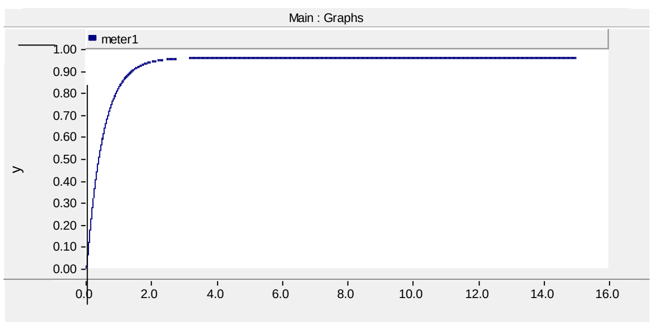

Figure 3: Simulation System without Faults

III. RESULTS AND DISCUSSION

A. Simulation Circuits with Fault without DSTATCOM

The distribution system that included the three phase balanced faulted was simulated for two second. The voltage sag had occurred at time 1.5 sec for duration 0.6 sec. Figure 4 shows the layout of the 11kV distribution line system under the effect of voltage sag generated by fault component. Real and reactive power meter is used to measure the real and reactive power in the distribution line system. The reactive powers are important part for STATCOM because it will generate the reactive power to mitigate the voltage sag that was occurred.

a. Simulation Results of Single Phase to Ground Fault

During fault at single phase in damage to land, it is categorized as a single line to ground. Single line to ground is one of the most common damage to the three-phase system. Based on the test systems, single fault line is assumed that the phase which has touched the ground since the system could not be loaded before damage was applied.

The percentage of voltage sag condition occurs and disturbs three phase balanced fault occurs at distribution line system. Illustrated diagram in Figure 5 shows Vrms has decreased from 0.959 to 0.672 per unit. This means that the total losses in the input voltage has an A phase to ground as many as 30% of the total losses in the input voltage has an A phase to ground. Changing the fault impedance can change the depth of the sag.

b. Simulation Results of Three Phase to Ground Fault

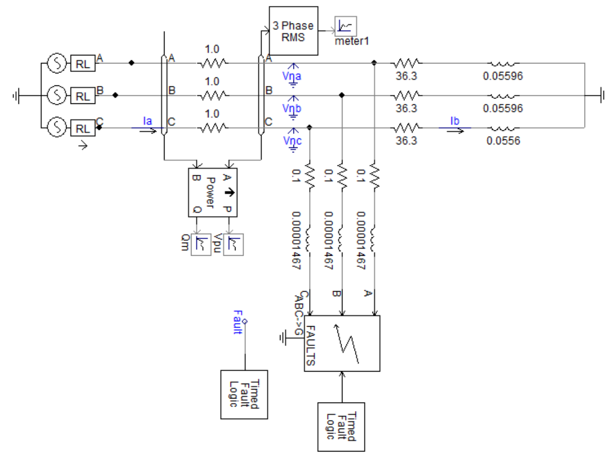

Figure 4: Simulation System with Fault without STATCOM

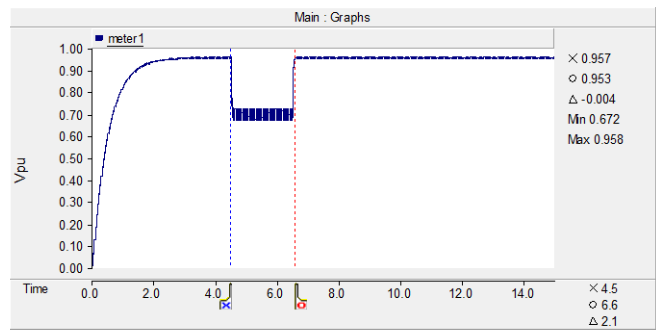

Figure 5: Simulation with Fault without STATCOM Single Phase to Ground

The voltage sag occurs and disturbs the system was available. Illustrated diagram in Figure 6 shows Vrms decreased from 0.959 to 0.052 per unit. This means that the total losses in the input voltage has an ABC phase to ground as many as 94.6% of the total losses in the input voltage has an ABC phase to ground.

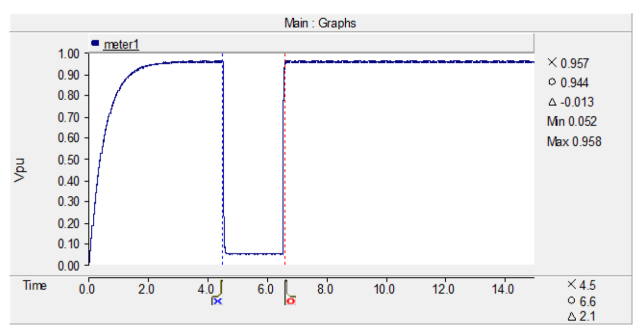

Figure 6: Simulation with Fault without STATCOM Three Phase to Ground

B. Simulation Circuit with Fault with 6-Pulse DSTATCOM

Based on Figure 7, the arrangement of six pulse inverter is connected to a Y-Y transformer. The differences in connection for transformer are needed to give 15 phase shift. In

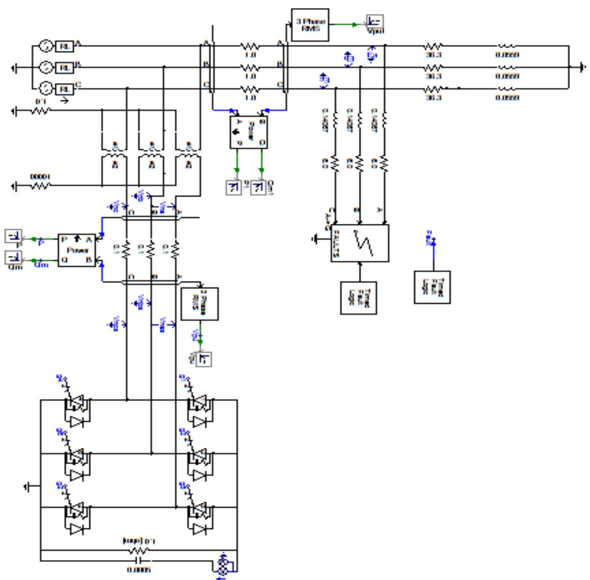

Figure 7: 6-Pulse D-STATCOM Circuit

simulation design 6-pulse D-STATCOM the sources are rated at 15MVA, 11 kV and 50 Hz. The switching frequency is set at 1.5 kHz. The important part of D-STATCOM is the control of reactive power by using reactive power control. This part will maintain the angle order to 15 degree.

a. Simulation Result with Fault and 6-Pulse DSTATCOM Single Phase to Ground

Figure 8 shows the effectiveness of D-STATCOM. It can be seen that after applied the DSTATCOM, the voltage sag occurring before has been mitigated. The graph shows the voltage value, Vrms was approaching to 1.0 per unit of 0.292 per unit. Percentage of Voltage sag has been rising by 70% and is proving that D-STATCOM reduce power quality problems.

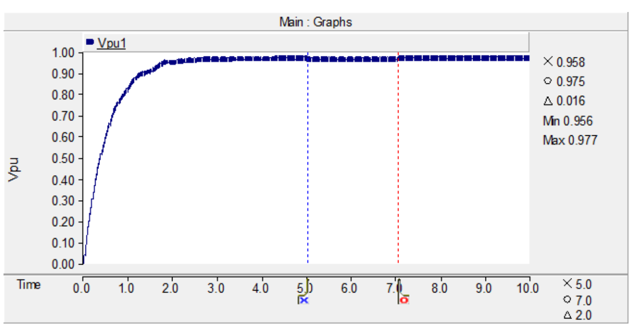

Figure 8: Simulation with Fault with 6-Pulse STATCOM Single Phase to Ground.

b. Simulation Results of Three Phase to Ground Fault

For the second case, Vrms as can be seen in Figure 9 shows that the sag has also been mitigated where Vrms was approaching to 1.0 per unit of 0.907 per unit. Percentage of voltage sag has been rising by 94.6% and is proving that D-STATCOM reduce power quality problems.

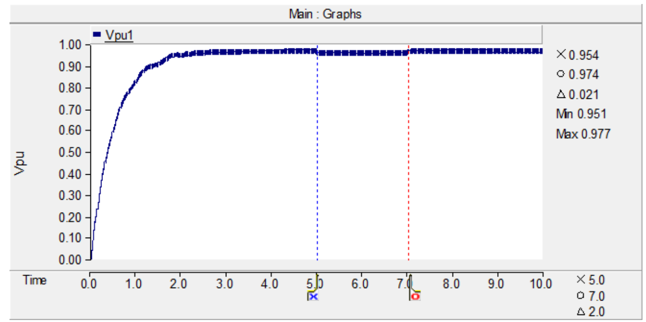

Figure 9: Simulation with Fault with 6-PulseSTATCOM Three Phase to Ground.

IV. Conclusion

The main purpose of this project is to investigate the performance of the power system network with and without FACTS devices installed in the system. From the result obtained, it can be said that 6-pulse D-STATCOM mitigation technique manage to mitigate and compensate the voltage sag of single line to the ground fault and three phase fault without any difficulty. The conclusion that can be drawn from this investigation is the performance of the power system with FACTS devices installed in it is better compared to the performance of the power system without the devices installed in it. So, it can be said that the power quality problem cannot be eliminated wholly, but it can be reduce causing the consequences of this problem to be minimize as much as possible. In addition, power quality problem can be avoided by ensuring all the equipment that been installed in the industrial are compatible with power quality in the power system. This can be attained by acquire equipment with duly technical specifications that merge performance of power quality with its operating electrical environment.

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