Power Quality Enhancement in Power Distribution System by Using Fuzzy Logic Controlled D-STATCOM

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Abstract—This Paper distinguished the problems related to distribution system in terms of clean power and their solutions, in the particular of compensation of reactive power. The abnormalities has been modelled and then analyzed. The deviations in the distributions system analyzed by the using D-STATCOM in the real time with the LCL passive filter. Fuzzy logic control scheme is implemented for the control of D-STATCOM so that it can make reactive power and THD under control. A SIMULINK model has been developed for the proposed system. Simulink results for various operating conditions has been obtained and analyzed for the merit of proposed control technique.

Keywords—D-STATCOM, Voltage Sag, FLC, LCL passive filter, THD

I. INTRODUCTION

In the present scenario power quality become major concern with the solid state devices, the performance is very close to the quality of power which is utilized by the utility centre. Utilities have the greater interest to utilize the existing power capacities. Power quality issues manifested to a undesired current or frequency or voltage that leads to the system in failure conditions or makes a misoperation at the consumer end. In today’s industrializations and modernisations of the power sector contains solid state power electronics devices like as IGBT’s, MOSFET’s and PLCs. All these devices are most affected by the quality of power such as harmonics, voltage swells/sag. Major power quality problems is voltage sags that contributes more than eighty percent of all these power quality issues. Voltage sags is decrease in rms amplitude value at the power frequency for a time period of few seconds. Different fault in the power system creates a voltage sag in the utility system. Fault at the customers end increases large current in the load system, resulted in the starting of motor or enerzitation of transformer. Typically faults like as single phase to ground or multiple phase with ground leads a very high current causes a voltage dip over the system impedance network. Voltage are hazards for the electronics equipment used by industry like as adjustable speed drive, robotics, programmable logic controllers. Different technique have been applied for the reduction or mitigations of voltage sag. Some conventional process are using bank of capacitor, implementation of parallel connected feeders or apply uninterruptible power supplies.

The power quality are not completely mitigated due to high cost of new feeders and controlled compensation of reactive power. A D-STATCOM (distributed static shunt compensator) are used for the mitigation of voltage sag as well as voltage stability, voltage flicker reduction. This paper consists a D-STATCOM with passive LCL filter and connected to 11kv distribution system in parallel or in shunted. The D-STATCOM also improve the power quality like as low power factor and harmonic distortion. In this paper section I represent introduction of test system. Section II describes the power quality issues such as voltage sag/swells. Section III represents modelling and principle of operation for the test system. Fuzzy logic control technique, system implementation and simulation results are discussed in the section IV, V and VI respectively.

II. VOLTAGE SAG AND SWELL

Voltage sag and swell is mainly caused by the faulty conditions short circuit, over load situations and on/off of high capacity motors. Injections of voltage by DVR to maintain and restore sensitive voltage to it’s normal operating value, for achieving zero power or minimum for compensation to the system by selecting a proper amplitude and angle between phase for a period of half of cycle to one minute. Voltage sag can happened at any instant with 10% to 90% of amplitude ranges of voltage. Voltage swells are defined as opposite of voltage sag i.e increment of rms value of voltage or current at frequency of power for a duration of 0.5 cycle to 60 seconds. Magnitude of voltage swells ranges from 1.1 to 1.8 increment value IEE519-1992 and IEEE1159-1995 standard are shown in fig 1.

Fig-1 IEEE 159-1995 STANDARD For Voltage Sag
III. BASIC STRUCTURE AND OPERATING PRINCIPAL OF D-STATCOM

The D-STATCOM is voltage source converter based shunt FACTs devices. It have capacity of absorbing or generating reactive power. The reactive source could be controlled. D-STATCOM is connected to the distribution system by coupling transformer to isolate the D-STATCOM from the distribution system. It’s need the device to be implemented as close to the most affecting loads to enhance the compensation in the distribution system. D-STATCOM injects only reactive power and plays major role on the weak ac system. D-STATCOM is composed of voltage source converter, filter and energy storage devices as shown in fig 2.

A) Coupling Transformer- It’s used to connect the D-STATCOM to the distribution system. It’s act as a isolation between D-STATCOM circuit and distribution system.

B) VSC(Voltage source Converter)- A voltage converter are composed of switching devices and storage devices, producing a sinusoidal voltage at desired instant of frequency, amplitude and angle of phase. Application of D-STATCOM is injects the compensating current into the distribution system on the basis of unbalance or distortion amount. Generally IGBTs is choose as a switching devices.

C) DC Link Capacitor - The capacitor act as a storage devices and provide dc link voltage at the standard value.

D) LCL Passive Filter- The configuration of LCL filter is shown in fig 3.

E) Principal of Operation -

The D-STATCOM are placed for the compensation of reactive power from which they are interconnected. It is producing 3 phase alternating voltage to a direct source of voltage. The magnitude of the voltage are controlled to maintain amount of reactive power to enhance the system voltage profile. Generally D-STATCOM voltage (Vsh) injected with phase the bus voltage (Vt). There is need of injected energy but reactive power to be absorb or injected by the D-STATCOM system. The compensation of reactive power is takes place by the changing the magnitude of out voltage of D-STATCOM.

The basic operating principal of D-STATCOM is described by fig 4. The output voltage of IGBTs (Vsh) is maintained in phase to the bus voltage (Vt) and. current output changes as Vsh [8,9]

I) $Vt < Vsh$ - Ish leads Vt by 90°. As a consequence leading reactive power produced by the D-STATCOM (i.e Capacitive mode)

II) $Vt > Vsh$ - Ish lag Vt by 90°. As a consequence lagging reactive power absorb by D-STATCOM (i.e Inductive mode)

III) $Vt = Vsh$ – No reactive power exchange to the active network.
IV. Fuzzy Logic Controller Scheme

The proposed model used fuzzy logic control as a controller. Mamdani proposed FLC for a system has number of input and output is only one. It is a mathematical system dealing along to the probability and soft computing provides. Fuzzy logic controller mainly used for controlling of inverter action. It follows “if x and y then Z” technique for getting solution of control problem on the place of mathematical approach of the system. Fig 5 shows the basic structure of FLC.

A) Estimation of Error- The error is estimated on the difference among the bus voltage and reference voltage. The rate of error is time rate of the error.

B) Fuzzification- Fuzzification is a process through which the crisp quantities are changes into the fuzzy, so the fuzzification process assign the membership value of the crisp quantities. Triangle membership function are used to the input and output as shown in fig 6.

C) Fuzzy Rule Base- The linguistic variables that are used are POS, POM, POB, NES, NEB, NEM and ZE. The fuzzy process is based on Mamdani method in this work. The set of rules for controller are shown in table. If then rule is used to describe the base rule.

Table I

<table>
<thead>
<tr>
<th>Rule Base of Fuzzy Logic</th>
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<tbody>
<tr>
<td>AES</td>
</tr>
<tr>
<td>NEB</td>
</tr>
<tr>
<td>NEM</td>
</tr>
<tr>
<td>ZE</td>
</tr>
<tr>
<td>POS</td>
</tr>
<tr>
<td>POM</td>
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<tr>
<td>POB</td>
</tr>
</tbody>
</table>

D) Defuzzification- The output of FLC is converted to crisp value by using defuzzification process. The output of fuzzy can not be used as it is in the application. So that conversion is must for the further processing. This is done by defuzzification method of centre of gravity.
V. MODELLING OF PROPOSED SYSTEM

In this study D-STATCOM is proposed to enhance the quality of power for the 11 kv distributed network. System is composed of a feeder that transfer power to distributed network at 50 Hz. The control strategy of the system is shown in fig 7.

![Flow Chart for Control Strategy](image)

D-STATCOM is placed at the distribution end. The simulation parameter are shown in Table II.

<table>
<thead>
<tr>
<th>No</th>
<th>System</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Inverter</td>
<td>IGBT based, 3 arm, 6 Pulse Carrier Frequency= 1080 Hz Sample time= 5u second</td>
</tr>
<tr>
<td>02</td>
<td>Three Phase Transformer</td>
<td>Nominal Power=100 MVA Frequency=50 Hz Magnetization Resistance Rm(pu)=500 Magnetization Induction Lm(pu)=500</td>
</tr>
<tr>
<td>03</td>
<td>Load</td>
<td>R=50 Ω L=300e-3 H</td>
</tr>
</tbody>
</table>

Proposed system are simulated on MATLAB 2012a which is shown in fig 7.

![Simulink Model of Test System](image)

VI. SIMULINK RESULT AND DISCUSSION

The test system are implemented for the various fault conditions such as single line ground, line to line, double line to ground, at various resistances.

<table>
<thead>
<tr>
<th>Various Faults</th>
<th>Faults Resistances</th>
<th>System Voltage(pu) Without DSTATCOM</th>
<th>System Voltage(pu) With DSTATCOM</th>
<th>% Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLG</td>
<td>0.68</td>
<td>0.829</td>
<td>0.965</td>
<td>16.40</td>
</tr>
<tr>
<td>DLG</td>
<td>0.78</td>
<td>0.751</td>
<td>0.978</td>
<td>30.23</td>
</tr>
<tr>
<td>LL</td>
<td>0.88</td>
<td>0.817</td>
<td>0.992</td>
<td>21.42</td>
</tr>
<tr>
<td>TLG</td>
<td>0.68</td>
<td>0.671</td>
<td>0.935</td>
<td>39.34</td>
</tr>
</tbody>
</table>

The table II shows the simulated results of voltage in pu for the various conditions. From the above results it is clear that the voltage profile of the system improved. TLG is most severe fault condition where the compensation of sag is more to improve voltage profile. Fig. 9 and fig. 12 shows system voltage value (pu) for various fault conditions at various resistances as shown in table II.
A) System Voltage Without D-STATCOM:

- Fig 8: Voltage at PCC at SLG
- Fig 9: Voltage at PCC at DLG
- Fig 10: Voltage at PCC at LL

B) System voltage with D-STATCOM: Fig 12 to Fig 16 shows the voltage of system with D-STATCOM at various fault and fault resistances. This is shows the compensation of voltage sag in the power system and voltage maintain within control.

- Fig 11: Voltage at PCC A TLG
- Fig 12: Voltage at PCC at SLG
- Fig 13: Voltage at PCC at DLG
VII. PERFORMANCE OF D-STATCOM WITH LCL FILTER

Fig 14- Voltage at PCC at LL

Fig 15- Voltage at PCC at TLG

Fig 16- THD of Current without Filter

Fig 17- THD of Current with Filter

Fig 16 and fig 17 shows the TOTAL HARMONIC DISTORTION (THD) for the current of D-STATCOM without LCL filter /with LCL filter. THD is 43.43% without filter although when filter is connected it’s improved to 0.73%.

VIII. CONCLUSION

The result obtained by the simulation represents that the mitigation is done for voltage sag by implementing D-STATCOM in the power distribution system. In addition to the fuzzy logic controller and LCL passive filter with D-STATCOM, THD is very less and power factor approximately close to the unity. Thus the power quality of the power distribution can be improved. D-STATCOM’s performance can be further improved by applying intelligent optimization such as ANNs and genetics algorithm.

REFERENCES


