Simulation and Analysis of Fuzzy based control strategy in DSTATCOM and DVR for voltage sag mitigation

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Abstract: The DSTATCOM and DVR by using Fuzzy controller are introduced to overcome the voltage sag issues. The DC and AC fault is applied to the different phases of the voltage individually; The simulation is performed to analyze the comparison of proposed DSTATCOM and DVR model with traditional DSTATCOM and DVR model. The results prove that the proposed model with fuzzy controller outperforms the traditional model. The proposed DVR model is found to be more effective to overcome the issue of voltage sag in comparison to the proposed DSTATCOM model.

IndexTerms - Distributed Power System, D-STATCOM, DVR, Voltage Sag Mitigation.

I. INTRODUCTION

The Voltage sag may be described as an event that takes place for a short period of time in which the voltage level of the signal gets decreased. It is usually determined with the help of two parameters that are as follow: magnitude and time duration. [1] The value of voltage sag generally lies in between 10% to 90% of the nominal voltage value and the time period of the signal varies from half cycle to one minute. Consider the three-phase system; in this, the voltage sag can affect phase to phase voltage as well as a ground voltage level. The circumstances that can result in voltage sag are a disturbance in the utility system, a breakdown in customer's facility system or the value of the load current varies quickly such as initiating a motor or energizing the transformer unit [2]. Generally, the fault arises due to single phase to ground or phase to phase short circuit that may result in a flow of a large amount of current signal. Now, because of this large amount of current, voltage drop takes over the impedance of the network. In case whenever the fault in the system takes place, then the voltage drop in the faulted phase occur, whereas in unfaulted phase it remains unaltered [3].

The problem arises due to voltage sags in transmission as well as distribution systems can be solved by implementing different techniques. In order to make the power applications more effective, the various types of controllers have been introduced that can be used with newly developed power electronic devices. These types of devices are used to coordinate and make the voltage level in the power system stable. [4,5] These devices are comprised of static power electronic device (PED) for controlling operation and also a static VAR generator and absorber. These types of devices can help in quick compensation reactive power of power system network. In order to enhance the system voltage profile and stability of the network under normal conditions as well as worse system conditions, these devices are used in the network [6].

In order to improve the capacity of transmission in the network and also to make the voltage level stable in the wide range of loads connected in the network; these types of devices are really helpful. The reactive component arises in the network due to variation in loads connected in the network can be compensated with these devices [7].

Consider a case where the value of the load component is high, then the requirement of reactive power increases hence a large amount of reactive power will flow in the system and that leads to a large amount of voltage drop in the transmission system. Hence it leads to a decrement in voltage level at the receiving end. On the other hand, if the load value connected in the network is low, then it will lead to an increment in the voltage level at the receiving side and it is because of the charging current. So it can be concluded that in case the produced reactive component has less value then the consumed reactive component then it will results in a voltage drop in the system and vice versa. Hence, the deviation in the voltage level is due to the disparity in the generated level and consumed level of reactive power component [8].

II. PROBLEM FORMULATION

With the advancement in the technology, power quality becomes an important factor for the consideration in the power systems. With the use of traditional systems, voltage sag remains constant. There are various causes due to which voltage sag happens. Utility distribution network, sensitive industrial load, and critical commercial operation suffer from a various type of outage and service interruption, which can cost significant financial losses. Consequently, traditional system faces a problem like voltage sag, voltage instability in power system with different fault conditions for LG, LLG fault. With the restricting of power systems and with shifting trend towards distributed and dispersed generation, the issue of power quality is going to take newer dimensions. To overcome the problem related to power quality custom power devices are introduced. As a result, D-STATCOM and DVR are used to supply the reactive power to maintain the power quality as well. Moreover, the control of these systems was done using the PI controller as it has the ability to reduce harmonics which is produced in the transmission line. From the survey conducted, it has been concluded that the use of fuzzy logic in comparison with PI controller gives optimum results.

III. PROPOSED WORK

The proposed work implements the DSTATCOM and DVR system by using the Fuzzy Inference model. The objective behind implementing the FIS is to improve the power quality and dynamic performance of the distributed power system. In the proposed model, the fuzzy system acts as a controller and it is observed that the fuzzy is one of the most suitable controllers for managing the performance of the power system because it is quite effective to handle the uncertainties. A fuzzy controller is considered as the most prominent controller in comparison to the traditional controllers as it did not use any mathematical model, easy to implement, efficient to deal with uncertainties, complicated ill-defined models etc. The figure below shows the flow of the proposed model for controlling the voltage mitigation in the distributed power system by using DSTATCOM and DVR system.

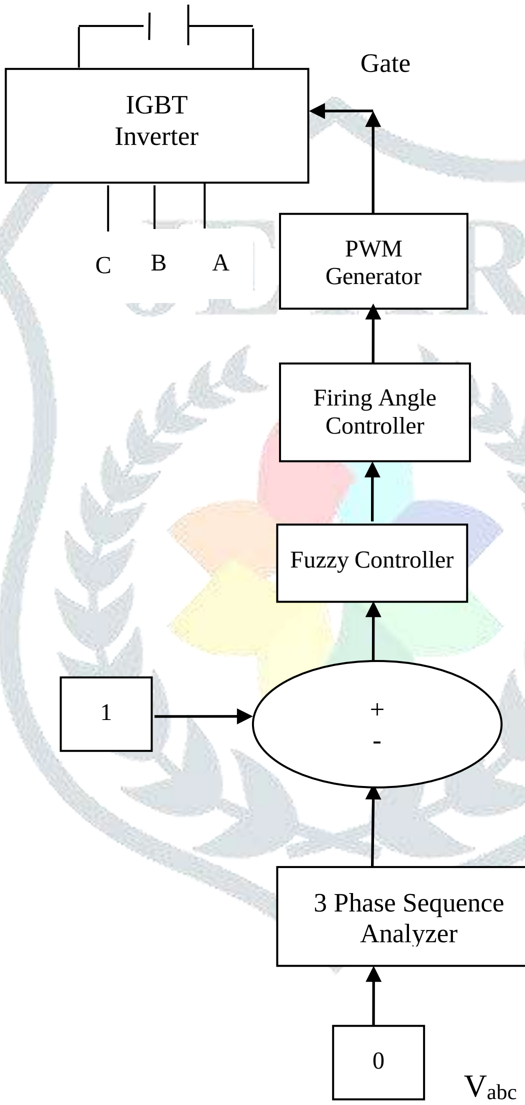

Figure 1 Proposed Framework

The figure defines that the proposed model comprised of an inverter, a PWM generator, a firing angle controller, fuzzy controller and three phase sequence analyzer. The IGBT inverter comprised of diodes that converts the DC signals to AC signals. Then a referral pulse is generated with 3 phase sequence analyzer in which the magnitude and phase is used to compare the referral pulse with a constant bit and then generate a pulse and pass it to the fuzzy controller where the output is generated on the basis of the error and change in error that is evaluated by the sequence analyzer. Then various trigonometric functions are applied to the output generated by the fuzzy controller. The final generated pulse is again passed to the IGBT inverter and then the final output is generated.

IV. RESULTS

This section of the work depicts the results that are obtained after implementing the proposed DSTATCOM and DVR model to perform the voltage sag mitigation process. The proposed DSTATCOM model implements the fuzzy controller to achieve the desired output. The proposed fuzzy inference model performs decision making process on the basis of the error and error change that occurs on the voltage of the power system. The figure 2 depicts the model of the proposed fuzzy controller. The figure shows that the proposed model consists of two input membership functions i.e. Error and Change error. The output membership function is Voltage Reference that is evaluated by applying the Mamdani FIS with 25 rules that are developed on the basis of two input membership functions.

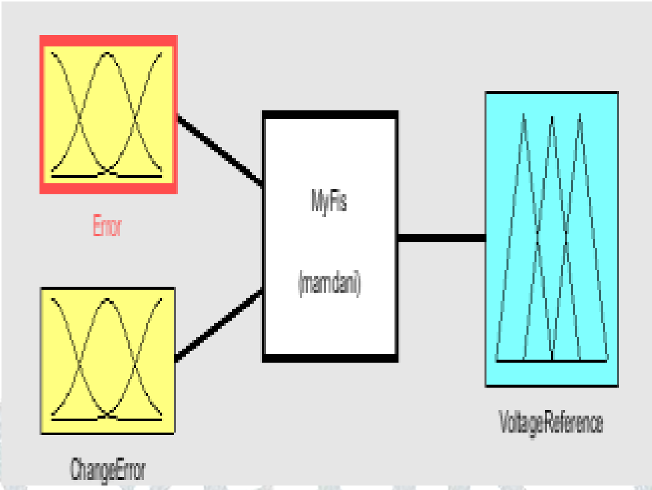

Figure 2 Proposed Fuzzy Inference System

The graphs in figures 3 and 4represent the input membership functions for proposed FIS. Figure 3 depicts the graph of Error and figure 4 represents the graph of Change error. The degree of both input membership function is between 0 and 1. The range of error lies within 0 and 1 with an interval of 0.1. The range is categorized into 5 various categories i.e. Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Small (PS) and Positive Big (PB). The category is defined on the basis of the ranges. Similarly, the figure 5 shows the output membership function.

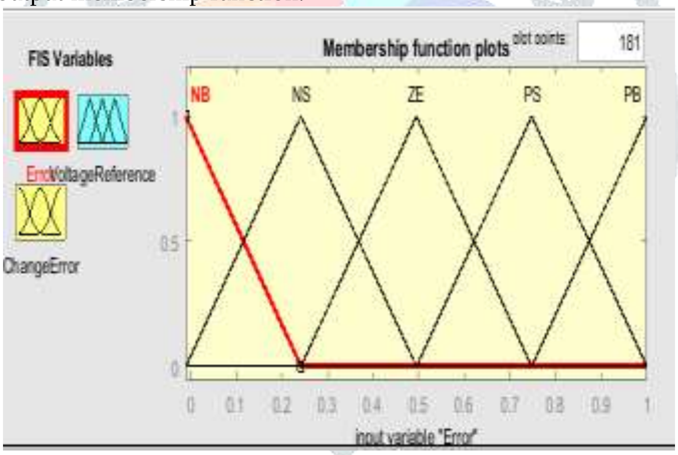

Figure 3 Input membership function “Error”

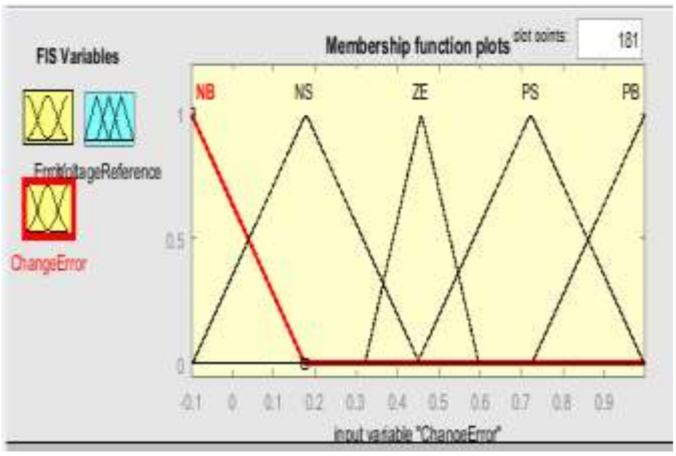

Figure 4 Input Membership function “Change Error”

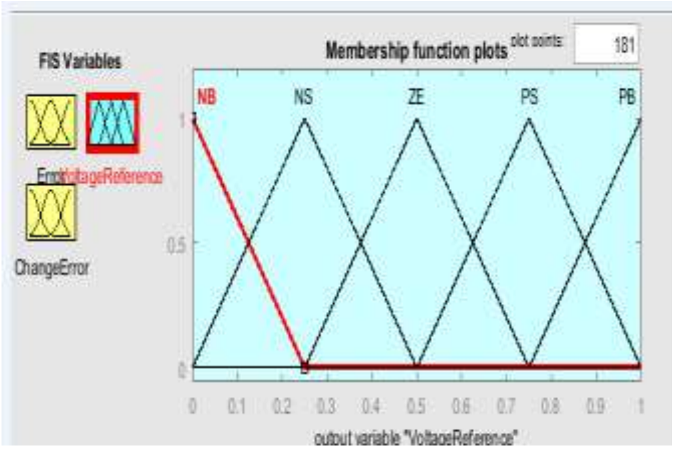

Figure 5 Output Membership function "Voltage Reference"

The output in FIS is generated by applying the set of rules that are created by using the input membership functions. The figure 6 shows the proposed set of rules of Mamdani FIS. The figure shows the range of the membership functions, connectors between both membership functions and the corresponding range of output membership function.

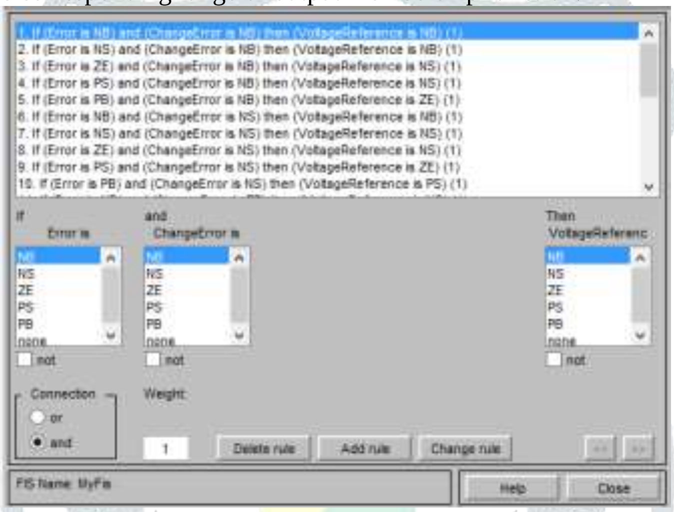

Figure 6 Rule set of proposed fuzzy inference system

The figure 7 and 8 show the voltage sag mitigation performed by traditional DSTATCOM and DVR model with the occurrence of the fault in the system. It is evaluated that the fault occurs at a higher level and voltage is reduced but after mitigating the fault the voltage is recovered to an extent by both systems i.e. Traditional DSTATCOM and DVR.

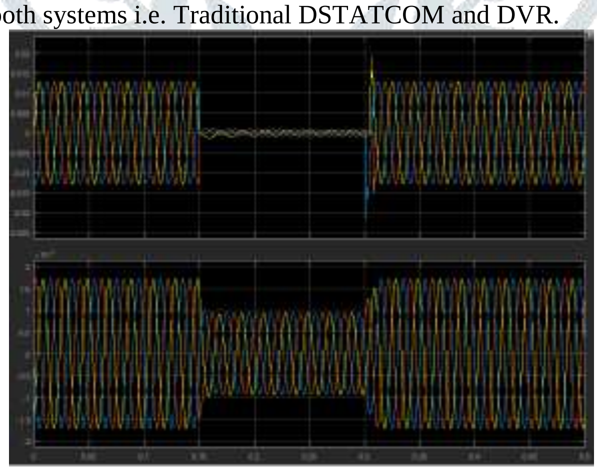
Figure 7 Voltage sag mitigation by traditional DSTATCOM model

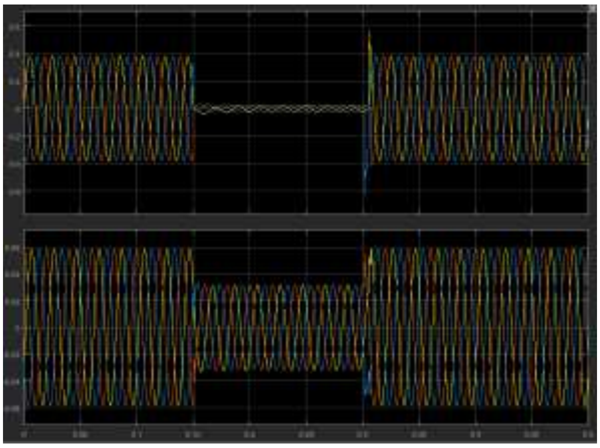

Figure 8 Voltage sag mitigation by traditional DVR model

For simulating the proposed work, the fault is introduced on the various phases of the voltage individually. The figure 9 depicts the voltage with the fault introduced at phase 1. The lower part of the graph represents the voltage in which the fault is mitigated by using the proposed DSTATCOM model. Similarly, the figure 10 shows the voltage in which the fault is introduced in phase 1 and mitigated by the DVR system. On the basis of both results, it is evaluated that the proposed DVR model is quite effective to mitigate the voltage in comparison to the proposed DSTATCOM model.

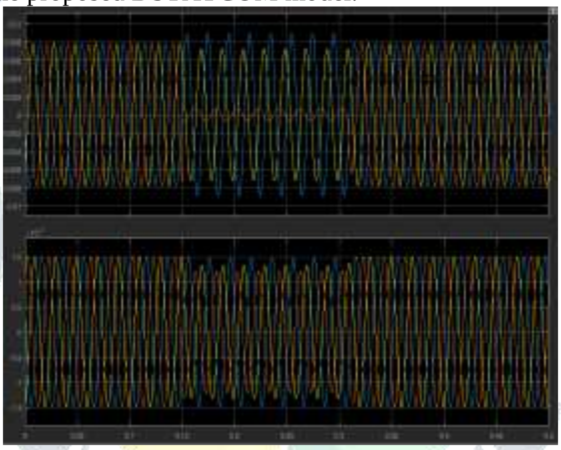

Figure 9 Voltage sag mitigation in phase 1 by proposed DSTATCOM model

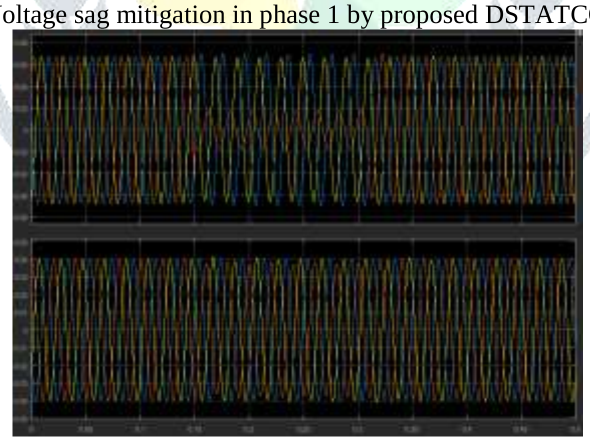

Figure 10 Voltage sag mitigation in phase 1 by proposed DVR model

The graphs in figure 11 and 12 show the results of the proposed work where the fault is introduced to the phase 2 of the voltage.

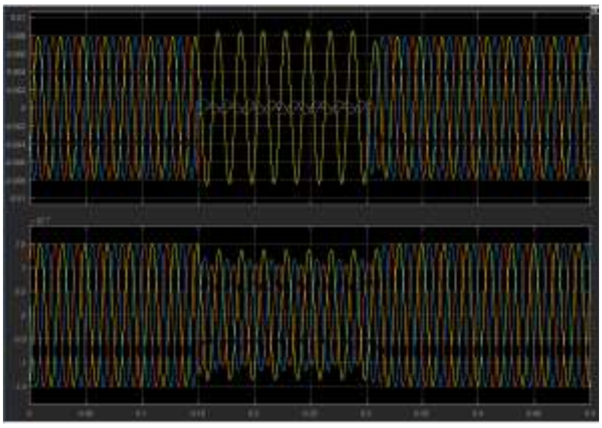

Figure 11 Voltage sag mitigation in phase 2 by proposed DSTATCOM model

After introducing the fault, the voltage is reduced to a higher extent. Thus to recover this reduction in the voltage, the proposed DSTATCOM and DVR model is applied and it is obtained that the DVR more effectively mitigate the voltage sag in contrast to the DSTATCOM model.

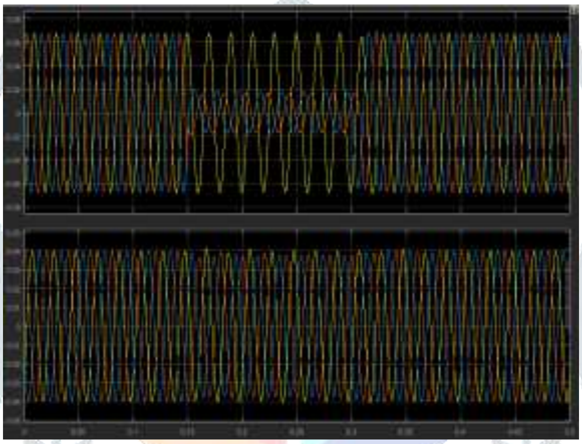

Figure 12 Voltage sag mitigation in phase 2 by proposed DVR model

The graphs in figure 13 and 14 depict the results for the proposed DVR and DSTATCOM model by adding the fault to the three of the phases of the voltage.

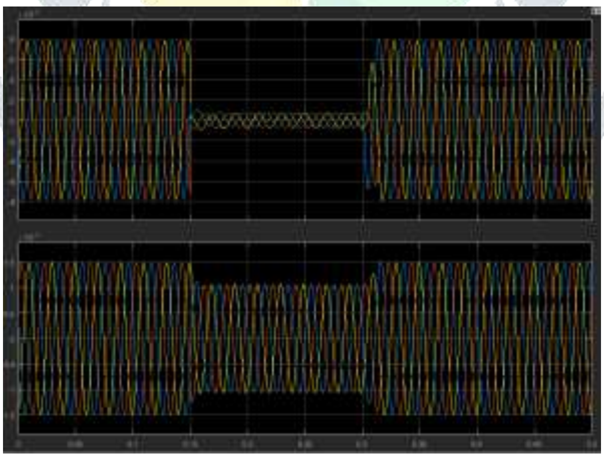

Figure 13 Voltage sag mitigation in phase 3 by proposed DSTATCOM model

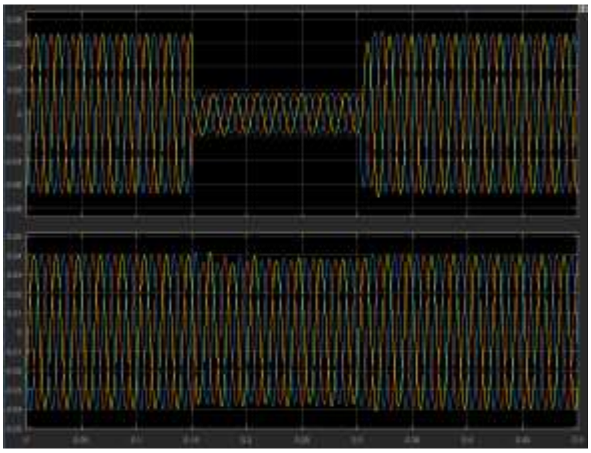

Figure 14 Voltage sag mitigation in phase 3 by proposed DVR model

After introducing the fault, the proposed DSTATCOM and DVR model is applied individually to the voltage to mitigate the sag or to reduce the effect of the fault on the voltage.

V. CONCLUSION

The distributed smart power grid systems suffer from various issues and voltage sag is one of these issues. In this, the voltage level reduced due to the occurrence of the fault. This study implements a system by using the DSTATCOM and DVR, the fuzzy controller is used to control the voltage to overcome the occurred faults. In this work, the DC fault is introduced to the each and every phase of the voltage i.e. single-phase, double-phase and 3-phase. Then the proposed DSTATCOM and DVR model is applied individually. After obtaining the results, is is concluded that the proposed DVR model outperforms the proposed DSTATCOM Model.

As the proposed work outperforms the traditional DSTATCOM and DVR model for mitigating the voltage sag but still more amendments are possible in this work in the near future to make it more efficient. In future proposed Fuzzy based controller could be hybridized with the PID controller.

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