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Fuzzy Based Positive Sequence Admittance and Negative Sequence Conductance with Dstatcom to Mitigate Voltage Fluctuations

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ABSTRACT:

In power systems, Voltage fluctuations are one of the power quality problems which are existing because of nonlinear loads, irregular distribution of single phase loads and loading types. Now a days, there are so many FACTs devices which are used for the improvement of the power quality. Distributed Static Compensator (DSTATCOM) is the one which can effectively reduce the voltage fluctuations. This paper illustrates the controlling technique of Fuzzy based negative sequence conductance and positive sequence admittance for the DSTATCOM to improve both negative and positive sequence voltages. It is found effective with the proposed control method in terms of its voltage regulation when it is simulated in the MATLAB environment.

I.INTRODUCTION:

Renewable energy sources such as photovoltaic, wind turbines, fuel cells etc. are preferred as they have low pollution with an additional advantage of in exhaustive in nature. In order to coordinate Renewable Energy Sources (RESs) intelligently with the micro grid concept was introduced into distribution networks for islanding operations and grid-connected [1], [2]. Reduction in system losses, defer in infrastructure investments and releave in network congestion are inferred with the increase in usage of RESs. These things have obtained much intension at present days, so many researches came in to picture to evaluate and explain functionality of Micro grids. For example,New Energy and Industrial Technology Development Organization [3] and Consortium for Electric Reliability Technology Solutions [4].

Usually, the single-phase loads distribution, loading types, transmission lines impedance would lead to voltage fluctuations in power system. This concept is much severe in case because of power flow in reverse direction with the Distributed Generations in either single phase or three phase connection [5]. The voltage fluctuations in the power system will lead to system losses, transformer overloading, capacity reduction, motor overheating and even results in sensitive equipment malfunction, protected devices nuisance tripping and output limitation of DGs. According to IEEE Std 1547.2-2008 [6], voltage fluctuations are restricted to ±5% as the renewable energy sources are operated in parallel to systems which are having low voltages. Voltage fluctuations indicated by %VUF Unbalance is kept below 2.0% to 3.0% which is acceptable for both utility and manufactures, where %VUF and %Unbalance are defined as the ratio of the negative-sequence voltage to the positive sequence voltage, and the percentage of maximum deviation from the average value respectively [7].

Hence, voltage regulation is absolutely required in grid connected operation to allow more DGs to join. On-load tap changer (OLTC) and Static VAR Compensator (SVC) are used at the substations and a switched capacitor or a step voltage regulator on feeders in order to realize voltage regulation in the power system. The voltage profile in the real time base can be achieved with the help of intelligent or optimal control on all the devices [8], [9]. With invention of semiconductor and its technologies, VSC based technologies like Unified Power Flow Controller (UPFC), Static Synchronous Compensator (STATCOM), Distributed STATCOM (D-STATCOM) and Active Power Filter (APF) are developed [10]–[14].

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STATCOM mode of voltage regulation is most widely developed and studied to regulate voltage in transmission systems whereas UPFC was invented to maintain reactive-power and real-power flows between the substations. APF and D-STATCOM are employed for improving the quality of power in the distribution systems such as, reactive-power compensation, harmonic damping and harmonic compensation.The operation of D-STATCOM for reducing voltage fluctuations at the load bus was explained [15].

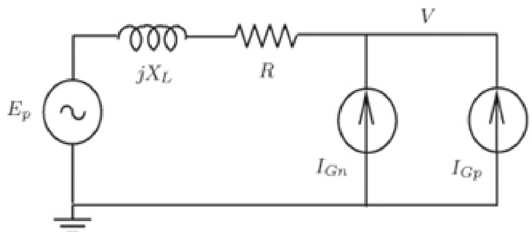

Fig.1. Modified circuit of the DG system.

Here, utility voltage regulation was performed by injecting reactive current. However, voltage regulation may experience the error because of the harmonic distortion or imbalanced voltage. In another paper, fundamental negative- and positive-sequence currents are individually controlled in order to improve the voltage regulation of D-STATCOM. However, Imbalance source is nearby the negative-sequence compensation.

In order to restore the voltage swell because of distributed generators a harmonic damping active filter was proposed. However, Positive sequence voltage controlling discussions are limited. The idea of VAR supporting with the help of inverter based RESs was explained to maintain voltage regulation locally.

Voltage fluctuation Compensation in DG systems by D-STATCOM was explained by Lee et al. In this paper, they extended the discussions and simulations as well as experimental verification. The proposed D-STATCOM realizes negative-sequence conductance and positive sequence admittance to control as well as suppress negative-sequence voltage and positive-sequence voltage.

Both negative-sequence conductance and positive-sequence admittance are dynamically modified according to imbalanced-voltage percentage and positive-sequence voltage deviation. Hence, Quality of voltage can be kept at an allowable level even with the variation of DGs or loads.

In order to control the fundamental current of D-STATCOM along with the reduction of harmonic current due to more voltage imbalances in the networks having low voltage a proportional–resonant (PR) current regulator which is capable of selective harmonic compensation is presented. Analysis of regulation of voltage along with simulation results validates the proposed approach.

II. DSTATCOM OPERATION:

D-STATCOM is being designed with a conventional 3-Ø voltage source inverter and it is connected to the distribution system through a step up transformer and its diagram is as shown in the fig.2.

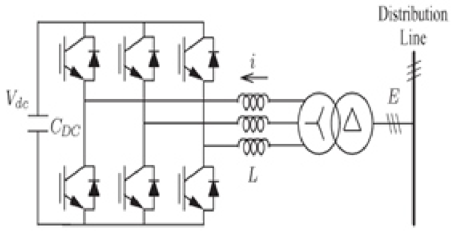

Fig.2. D-STATCOM power circuit

The proposed D-STATCOM operates as fundamental negative-sequence conductance and fundamental positive-sequence admittance as given in eq.1

$$i^* = Y_p^* \cdot E_f^{+\prime} + G_n^* \cdot E_f^- \qquad \text{-------- (1)}$$

Where i* indicates the reference current, |Ef+| indicates the quadrature fundamental positive-sequence voltage, and |Ef-| is the fundamental negative-sequence voltage.

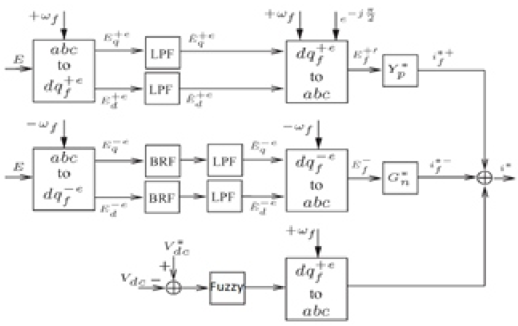

Fig.3. Generation of reference current.

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A. REFERENCE-CURRENT GENERATION:

Synchronous Reference Frame (SRF) theory is used to realize the control circuit as shown in Fig. 3. To filter out ripple components, a Low Pass Filter is used to generate the positive-sequence voltage Eeqd+e along with Low Pass Filter a band rejected filter which is tuned at the second-order harmonic frequency is required in order to find out the negative-sequence voltage Eeqd-e. With the application of reverse transformation, and the negative sequence voltage |Ef-| and the quadrature fundamental positive-sequence voltage |Ef+'| in the three-phase system are available, where |Ef+'| is lagging behind the fundamental positive-sequence voltage with an angle of 90. and

the negative-sequence current command If and The positive-sequence current command If*+are equal to and multiplied by Gn* and |Ef+| ,multiplied by Yp* and |Ef-| respectively . therefore the reference current i* is obtained as shown in the eq.1. For the proper operation of the D-STATCOM, a fuzzy controller is utilized to generate a fundamental current which is in phase with the positive-sequence voltage in order to retain the voltage of the DC bus Vdc at the reference value of voltage Vdc*.

B.FUZZY LOGIC CONTROLLER:

Now a days, with increase in the number of applications and varieties, the importance for the fuzzy logic have increased drastically. The fuzzy logic ranges from consumer equipments like washing machines camcorders, microwave ovens and cameras to industrial process control, decision-support systems, portfolio selection and medical instrumentation. Rules in a fuzzy inference system are obtained from the simple logic rules which are available in the tool box. The toolbox which is available can be used as a standalone fuzzy inference engine. On the other hand, we can employ fuzzy inference blocks in the MATLAB simulink and the total system simulates the fuzzy systems.

Fuzzy Logic Toolbox allows the MATLAB technical environment with tools in order to design fuzzy logic. Graphical user interfaces (GUIs) allows the methods of fuzzy inference system design. For most common fuzzy logic methods, along with adaptive neuro fuzzy learning and fuzzy clustering the functions are provided.

C. FUZZY LOGIC TOOLBOX WORKING:

The Fuzzy Logic Toolbox develops GUIs in order to perform pattern recognition and simple fuzzy system development. We can analyze and develop fuzzy inference systems, with the use of toolbox we can develop adaptive neuro fuzzy inference systems and can perform fuzzy clustering. In addition to the above, the fuzzy logic toolbox allows us to use fuzzy controller block that can simulate a fuzzy logic control system and Simulink to model. From the Simulink along with the fuzzy logic we are capable of generating a C code embedded applications.

D. CONTROL OF CURRENT:

Current command is based on the i*, the current measuring is i, and the voltage measuring E, the current regulator shown in below.

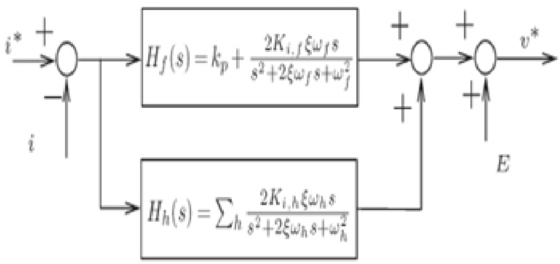


Fig.4. Current control.

Fig. 4 produces for space vector pulse width modulation (PWM) control voltage command v* of the inverter. The defined of transfer functions H f(s) and H h(s) are bellow equations as

$$H_f(s) = k_p + \frac{2K_{i,f}\xi\omega_f s}{s^2 + 2\xi\omega_f s + \omega_f^2}$$

$$H_h(s) = \sum_h \frac{2K_{i,h}\xi\omega_h s}{s^2 + 2\xi\omega_h s + \omega_h^2}$$

Where Kp means proportional gain, the fundamental frequency and its integral gain is Wf and Ki,f are respectively and the harmonic frequency and its integral gain represented as Wf and Ki,h respectively. The current regulation is tuned with damping ratio ξ is used to tune the current regulation to establish a peak of narrow gain concentrated at the fundamental frequency for tracking of the fundamental current and it will also introduce different narrow gain peaks to reduce current distortion near harmonic frequencies.The control of parameters Yp* and Gn* is shown in the below fig.

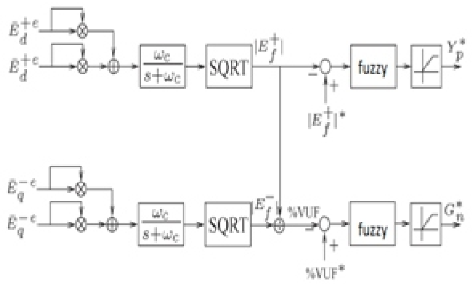


Fig.5. control of parameters Yp* and Gn*

|Ef+|and |Ef-| are defined in the equation %vuf. They can be approximately calculated by using SQRT and Low Pass Filter operation, where Low Pass Filters are considered at cutoff frequency ωc= 10 Hz in order to filter out the ripple components. After that, a Fuzzy controller is designed in order to produce Yp* in order to balance |Ef+|at prescribed value |Ef+|*. Therefore, Voltages can be maintained at its permissible level with control of Gn*. and imbalanced voltages are suppressed. Here, %VUF (percentage of voltage imbalance factor) is used to to indicate the level of imbalanced voltage and it can be defined as the ratio of the negative-sequence voltage to the positive-sequence voltage.

$$\left|E_f^+\right| = \sqrt{\frac{\int_t^{t+T} \left(E_q^{+e}(t)^2 + E_d^{+e}(t)^2\right)}{T} dt}$$

$$\left|E_f^-\right| = \sqrt{\frac{\int_t^{t+T} \left(E_q^{-e}(t)^2 + E_d^{-e}(t)^2\right)}{T} dt}$$

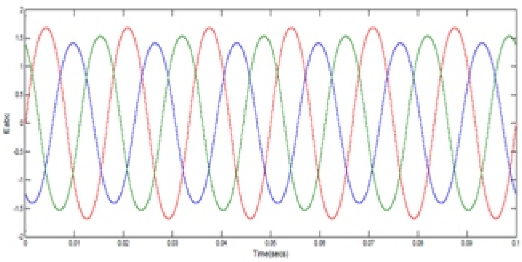
$$\%\mathrm{VUF} = \frac{\left|E_f^-\right|}{\left|E_f^+\right|} \cdot 100\%.$$

III. SIMULATION RESULTS AND DISCUSSIONS:

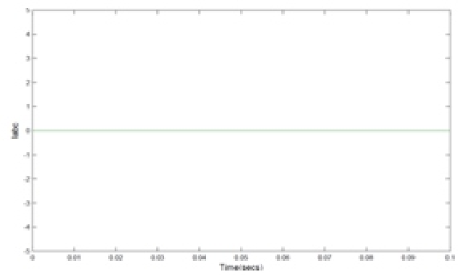
A Power system network rated at 23 KV and 100 MW is designed which is used to illustrate voltage fluctuations and to check the performance of the proposed D-STATCOM. As the voltage of grid at the end of a line is very much sensitive to the addition of both reactive and real powers depending on the load flow analysis, so, the D-STATCOM is installed at the end of the line.

A. STEADY-STATE OPERATION:

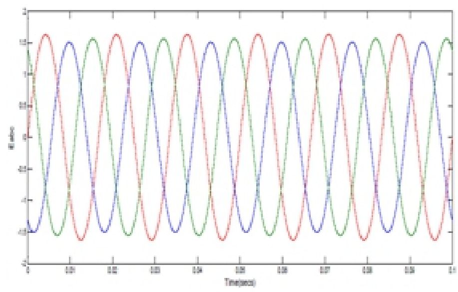
Without the operation of D-STATCOM the voltages are swelled and imbalanced, Fig. 6(a) indicates that voltages at the buses are considerably imbalanced and swelled because of the single phase loads and distributed generation. Fluctuations in the voltages is very much high at the end of the lines. However, Fig. 6(c) indicates the fluctuations in voltage which is significant due to the presence of imbalanced voltage. After the suppression of the imbalanced voltages, Fig. 6(e) indicates the voltages which are fully recovered from the voltage fluctuations.



(a)



(b)



(c)

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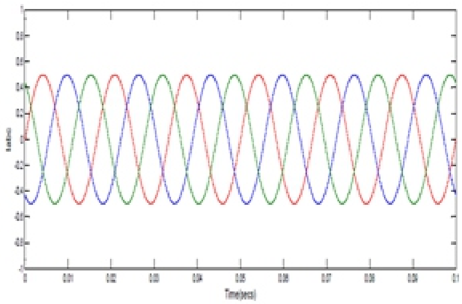

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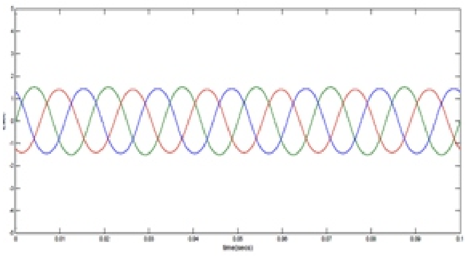
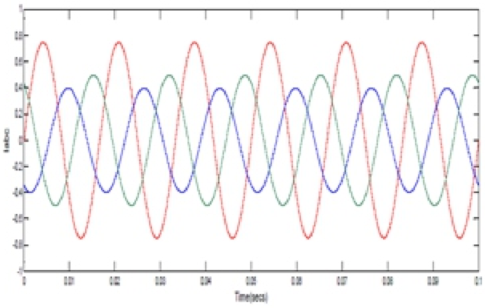


(e)



(f)

Fig.6: Simulation results (a) Eabc during D- STATCOM off (b) Iabc during D- STATCOM off (c) Eabc during D- STATCOM on but Gn*=0 (d) Iabc during D- STATCOM on but Gn*=0 (e) Eabc during D- STATCOM on (f) Iabc during D- STATCOM on.

B. TRANSIENT OPERATION:

Different cases are used to calculate the transient performance of D-STATCOM. fig.7&8 shows the transient behaviors of |Ef+|and %VUF, while Fig. 9&10 shows those of Yp*and Gn*. Gn* is reduced to maintain %VUF at 2%, as shown in fig. 10. At t = 8s, the power output of the DG reduces from 0.9 to 0.45 p.u. Since the voltage swelled is adjusted to lighter Yp* and the reactive power of the D-STATCOM supplied is reduced.

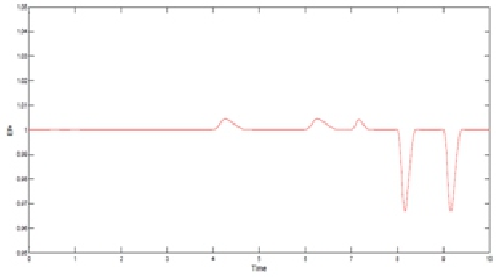


fig:7. Voltage in transient of Ef+

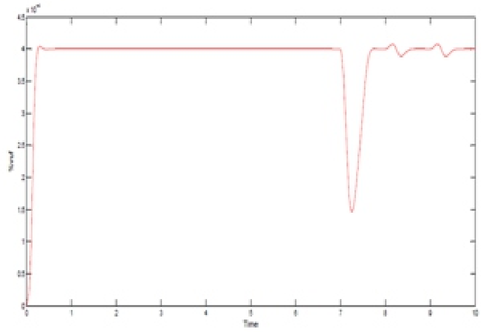


Fig:8. Voltage in transient of %VUF

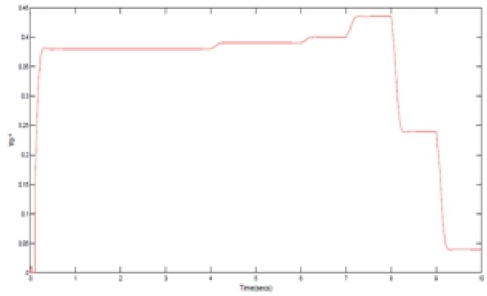


Fig: 9. D-STATCOM commands in Yp*

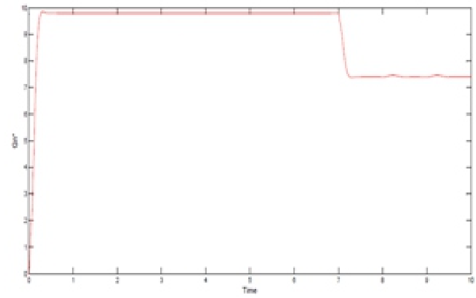


fig:10. D-STATCOM commands in Gn*

CONCLUSION:

In this paper, fuzzy logic controller along with negative sequence conductance and positive sequence admittance was used to control the D-STATCOM which reduces voltage fluctuations in Distributed Generation systems. In order to maintain both negative and positive sequence voltages at tolerable level a tuning control is implemented to dynamically vary conductance and admittance commands. DSTATCOM operation and its voltage regulation during different situations have been discussed. By adjusting conductance and admittance the operation of DSTATCOM is controlled, the compromise between the required improvement on power quality and the D-STATCOM rating can be accomplished.

The D-STATCOM in the proposed method can be implemented at the same location in order to mitigate voltage fluctuations in Distributed Generation systems using fuzzy logic controller along with negative sequence conductance and positive sequence admittance, hence, more Distributed generations can be allowed online. At last, the D-STATCOM cooperative control has been discussed. The D-STATCOM along SVC and OLTC to control the voltage of the grid by employing a low-frequency communication.

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