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Application Transformer In Logic Fuzzy Control System For Voltage Injection

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ABSTRACT

In the production and distribution of electricity, like anything else, there is a possibility of errors, and some of these errors are unavoidable, such as having different voltage fluctuations. But these minor errors also increase the possibility of damaging the internal network system and even electrical appliances. Hence, a power transformer can make the oscillating input power become a non-oscillating output power. In some cases, the electricity consumption may suffer a severe drop, i.e., lack of voltage. In this case, having a transformer that increases in time means that the voltage improves, and or voltage swell can compensate for the drop or sag, which is important for us. However, by designing and using power electronic circuits and a fuzzy logical control system in the MATLAB software environment and by simulation, we can control these voltage fluctuations. We call this type of transformer application transformer voltage injection. Although based on the application, we can say that the transformer can be used as a power supply, impedance matching, a voltage isolator, and as an input and output.

KEYWORDS: Errors, Fluctuations, Injection, Transformer

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1. Introduction

In 1831, the transformer was invented based on Faraday's law of electromagnetic induction. The electrical energy produced in the power plant is used in different ways after being transferred to the consumer. The devices that consume the generated electrical energy are designed in such a way that they receive the electricity produced by the power plant in the same form and voltage level as it is, and on time, and consume it. The power reduction will be transmitted. Therefore, the use of the power transformer remains constant at certain intervals so that the consumed power is equal to the produced power[1].

Nowadays, electricity plays a role like the role of water or air in our lives. If they are removed from our lives for a day or maybe just an hour, our lives will suffer severe disturbances. For this purpose, the role of the voltage injection transformer is investigated with fuzzy logical control systems, or its abbreviation is FLC. However, the simulation results show the moments of voltage injection.

2. The Concept Of The Voltage Sag

The voltage sag or voltage dip is a short-duration reduction in RMS voltage, which can be caused by a short circuit, overload, or the starting of electric motors. Voltage sag, as defined by IEEE-1159-1995, happens when the RMS voltage decreases between 10 and 90 percent of the nominal voltage for one-half cycle to one minute. In this definition, there are thresholds for both maximum and minimum voltages. Any voltage drop below 10% of the nominal voltage is considered a cutoff or interruption. Voltage sag between a half cycle and 30 cycles is called instantaneous voltage sag, and voltage sag between 3 seconds and one minute is called temporary voltage sag; voltage sag more than one minute is called voltage reduction, and voltage sag less than half a cycle is called transient[7].

3. Using Voltage Injection Transformer In The System Dynamic Voltage Restorer

As illustrated in Fig. 1, the general structure of the dynamic voltage restorer includes a DC energy storing unit, a capacitor, a voltage source inverter, a low-pass filter, a voltage injecting transformer, and the controlling system.

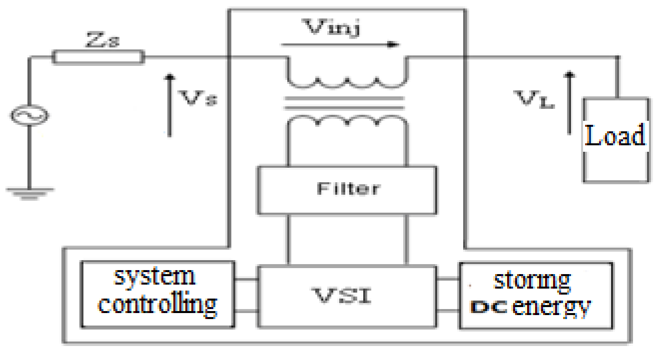


Figure 1. In the dynamic voltage restorer system, it has been shown the connection location of the voltage[6]. injection transformer (Vinj).

The main duty of the dynamic voltage restorer is to inject a dynamically controlled voltage ($V_{inj}V_{inj}$) to the load side; this is done using a transformer located between the sensitive load and the feeding source. Any voltage sag caused by a disturbance in a malfunctioning feeder is compensated with an equal voltage. The voltage difference between the reference voltage and the dynamic voltage restorer is injected voltage is applied to inverter in order to generate nominal voltage in the load pulse width modulation (PMW) [6].

4. Recognition Of Control Gains And Error Signal EΔ In Fuzzy Logic Controllers

Considering that the output voltage of the controller is connected to pwm, and on the other hand, the voltage injection transformer is considered one of the pvm components here, in order to understand the classic controller in the form of equation 1, where the Kp and Ki gains are correctly specified, start and then the fuzzy logic controller is investigated[1].

$$U(t) = Kp\ \varepsilon(t) + K_i \int \varepsilon(t)\ d\ (t) \quad (1)$$

In which U is the controller output that is applied to the PMW. Kp and Ki are the fixed controller gains that depend on system parameters. ⍰ is the error signal as the difference between the reference voltage and injected voltage. Equation (1) shows that the maximum and minimum values of Kp and Ki (gains) are determined by the trial-and-error method. In case the coefficients exceed the allowed value, the controller goes to an unstable status[8]. This is the drawback of the PI controller and its inability to react for abrupt changes in the error signal ε; since, this controller has only the capability of detecting the instantaneous value of error signal and has not the ability to take into account direction (upward or downward) of the error signal, which is mathematically equivalent to derivative of the error signal (εΔ). As a result, it is necessary to examine the fuzzy logic controller to obtain more accurate results

5. Fuzzy Logic Controller

Depending on the value of the error signal ε, fixed parameters are adjusted with fuzzy controller system; in other words, online fitting and adjusting PI controller gains are performed with a fuzzy controller, making a fuzzy logic controller. The block diagram of a fuzzy logic controller is illustrated in Fig. 3[2].

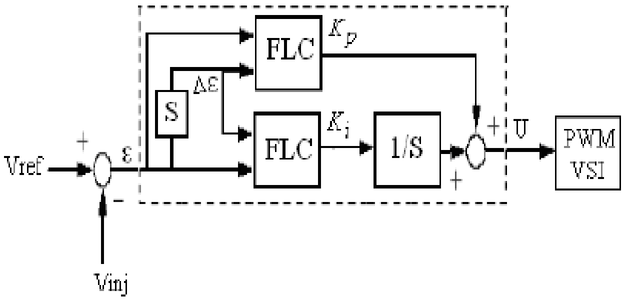


Figure 3: fuzzy logic controller[3].

Fuzzy system structure and its governing rules are determined with trial and error method, and control output signal is determined with a fuzzy inference engine, in which a set of conditional rules is utilized. As illustrated in figure 4, with fuzzy logic controller, the values of Kp and Ki are changed according to error magnitude (⍰) and its changes (εΔ)[3].

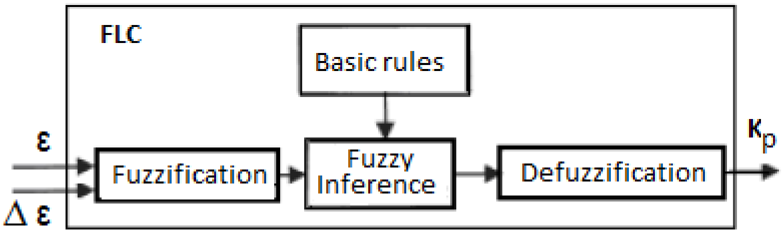


Figure 4. fuzzy logic controller operation (FLC)[5].

5. Voltage Injection(Vinj)By Transformer In Simulink Model

In the simulation, according to the written data, the role of the voltage injection transformer is particularly important, as in the controller model, the value of the rated voltage of the load is equal to the difference between the reference voltage and the voltage injected with the voltage injection transformer which is shown in Figure 5, so the experimental values are given as follows[2]: Voltage source inverter: full bridge based on IGBT with a 12 KHz PWM generator, Transformer coupling conversion ratio of 1 to 1, energy storing capacitor bank of $88 \times 10^{-4} 88 \times 10^{-4}$ F, DC link voltage of 850 V, LC filter parameters with $C_F C_F$ =$220\mu F 220\mu F$ in series with the damper resistor $R_d R_d$=$0.5\Omega 0.5\Omega$, $L_f L_f$ =$0.6\Omega 0.6\Omega$, input voltage of $220\ V_{rms}$ $220\ V_{rms}$ with the frequency of 50 Hz feeding a RL load with R=10/3Ω and L=60 mH. The load is non-linear, including a diode rectifier[4]. This load is connected to the dynamic voltage restorer via an internal load with a small inductance of $L_{in} = 1\ mH L_{in} = 1\ mH$.

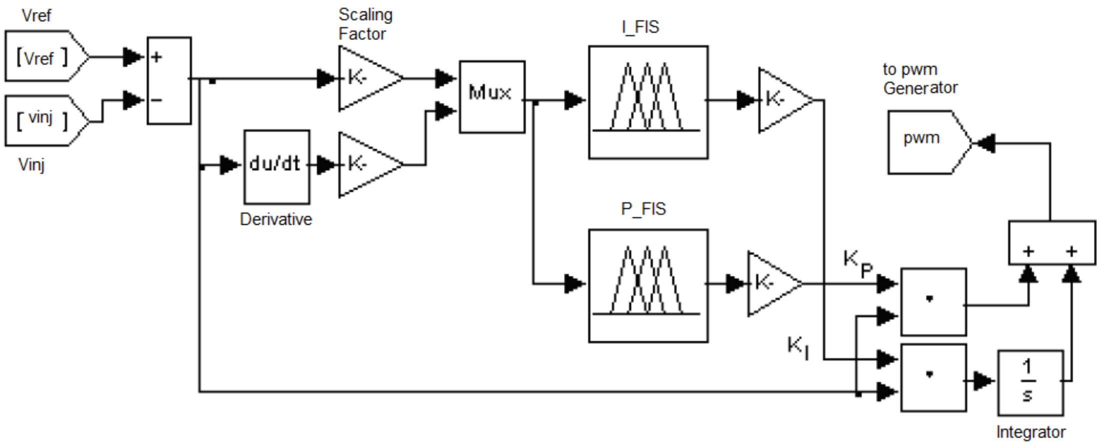


Figure 5. Simulink model of fuzzy logical controller [8].

Power source is simulated as an ideal source in series with source impedance $L_s L_s$. For a weak power system (relatively high feeding impedance), it is assumed that L_C=16.5×10^{-5}H.Three phase 50% of amplitude voltage sag is simulated, however, only the results of 1 phase are shown, for simplicity[7]. Regarding the importance of the dynamic voltage restorer in enhancing weak power systems, the results are shown in figures 6a, b, c, d, e. The division of the time axis is such that, for example, the figures 6a, b, c, d, e, figures illustrate the performance of the system. In this case, the voltage sag starts at 100 ms and continues until 160ms, in which the total time for the voltage sag is 0.06 s.

As shown in figure 6a, in the injection voltage, the shortage starts at 0.1 s and continues to 0.16 s. For this case, And the rest of the divisions can be understood accordingly. According to diagrams 6a, b, c, d, e. diagram 6a shows the state of the injected voltage to compensate for the voltage drop. Diagram 6b shows the state of the nominal voltage of the load, which means that the voltage drop did not occur. Diagram 6c shows the voltage drop in the power supply on the consumer side. As a result, the voltage injection transformer is activated, and according to diagram 6d, the amount of voltage reduction determined with the fuzzy logic control system is injected into the distribution line with the voltage injection transformer, and finally, according to diagram 6e, the rated voltage of the load is supplied, and this cycle is shown in Every time it works, it will improve the rated voltage of the load.

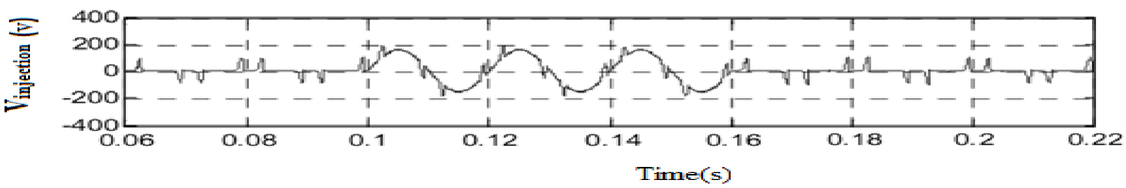


Figure 6a. voltage injection by voltage injection Transformer

Diagram 6a, shows the state of the injected voltage to compensate for the voltage drop.

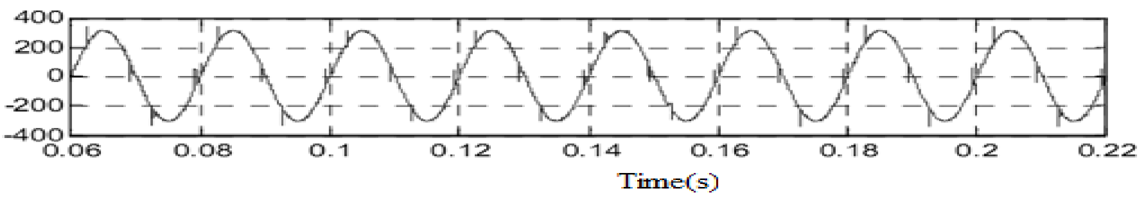


Figure 6b, It shows the nominal load or consumer voltage without any voltage drop. Diagram 6b shows the state of the nominal voltage of the load, which means that the voltage drop did not occur.

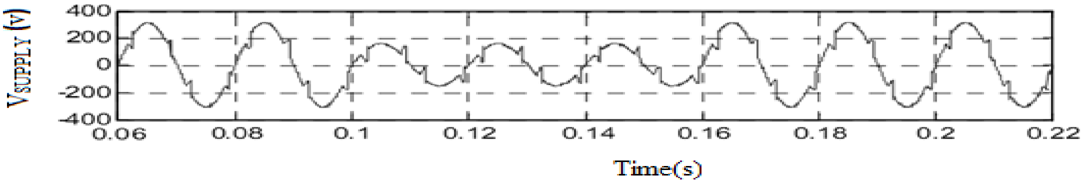


Figure 6c. shows the voltage drop in the power supply on the consumer side.

Diagram 6c shows the voltage drop of the power supply on the consumer side[6]. As a result, the voltage injection transformer is activated, and according to diagram 6d, the amount of voltage reduction determined with the fuzzy logic control system is injected into the distribution line, and finally, according to diagram 6e, the rated voltage of the load is improved.

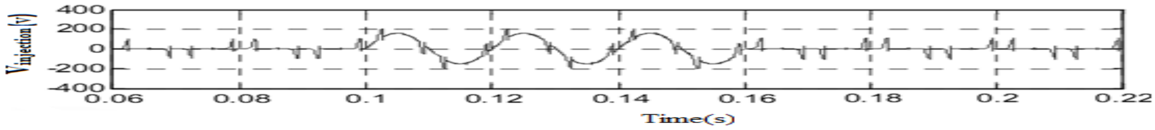
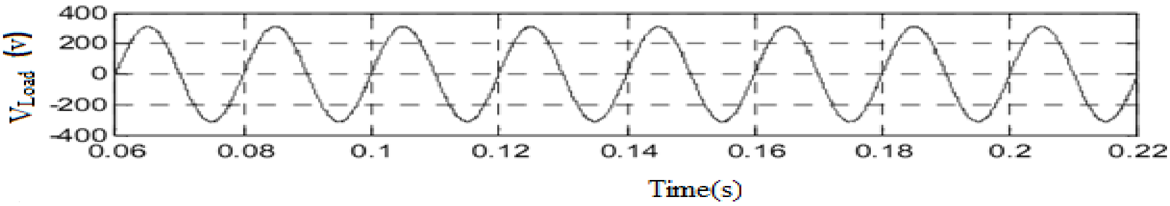


Figure 6d. Voltage injection by the voltage injection transformer at the moment of reducing the supply voltage[5].

Diagram 6d. As seen, the voltage drop is controlled, and the transformer injects the drop value in to the distribution line at the same instant of time



Figurs6e. load voltage compensate with injecting the transformer voltage in the fuzzy logic controller

7. Conclusions

In power distribution systems, low voltage is usually characterized with amplitude and time interval variations. The main cause of lack of voltage in power grids is short circuit errors and power supply to transformers and induction motors. The dynamic voltage restorer is one of the most effective and efficient devices to improve the voltage deficiency with using a fuzzy logic controller in order to reduce disturbances in the supply voltage and keep the load voltage constant and stabilize it in the nominal value.

Dynamic voltage recovery with having an injection transformer injects the right voltage into the network. In addition to reducing the harmonic distortion of the load voltage, its ability to improve the voltage deficiency and reduce the problem of adjusting the controller coefficients. According to the results of the simulations, it was found that the voltage drop is effectively reduced with the voltage injection transformer. Therefore, it is recommended to use the transformer in the controller as a voltage injector to improve the voltage reduction.

Refrences

Kasuni Perera, M.V., 2007, "Control of a Dynamic Voltage Restorer to compensate single phase voltage sags", Master of Science Thesis, Stockholm, Sweden.

Nguyen, P.T., Saha, K., 2004," Dynamic Voltage Restorer Against Balanced and Unbalanced Voltage Sags: Modelling and Simulation", IEEE.

Mallela, V.S., Solanki, P.S., Chaturvedi, A., 2005, "Role of a Dynamic Voltage Restorer in Mitigation of Power Quality Problems", International Conference on Communication, Power

Banaei, M.R., Hosseini, S.H., 2006, "Verification of a new energy control strategy for dynamic voltage restorer by simulation", ELSEVIER, Simulation Modelling Practice and Theory 14 ,112–125.

Benachaiba, C. Ferdi, B. "Voltage Quality Improvement Using DVR", Electrical Power Quality and Utilization, Journal Vol. XIV, No. 1, 2008.

Nemati, M. Yousefian, H. A. Afshari, R. "Recognize The Role of A DVR in Power Systems" International Journal of Recent Trends in Engineering, Vol 2, No. 7, November 2009.

M. A. El-Gammal, A. Y. Abou-Ghazala, and T. I. El-Shennawy , 2010 , Effects of Voltage Sags on a Refinery with Induction Motors Loads , Iranian Journal Of Electrical And Computer Engineering, Vol. 9, No. 1, Winter-Spring.

Omar, R., Abdrahim, N., 2009 ," Mitigation Of Voltage Sags/Swells Using Dynamic Voltage Restorer (DVR)", ARPN Journal of Engineering and Applied Sciences, Asian Research Publishing Network, VOL. 4, NO. 4.