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DVR Implementation for Compensation of Sag/Swell using Fuzzy Logic Controller

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ABSTRACT

Voltage sag is a common and undesirable power quality phenomenon in the distribution systems which put sensitive loads under the risk. An effective solution to mitigate this phenomenon is to use dynamic voltage restorers and consequently, protect sensitive loads. The protection of the sensitive but unbalanced and/or non-linear loads from sag/swell, distortion and unbalance in supply voltage is achieved economically using a dynamic voltage restorer (DVR). Such devices are used to protect sensitive loads on distribution electrical systems, placing it in series with sensitive loads. This paper presents a DVR performance under such events, able to compensate sags/swells in two cycles. A peak detector and the in-phase compensation method are used to get quick and accurate responses. The compensating voltages when injected in series with a distribution feeder by a 3-single phase H-bridge voltage source converter (VSC) with constant switching frequency hysteresis band voltage controller, tightly regulate the voltage at load terminals against any power quality problem on the source side. A capacitor supported DVR does not need any active power during steady state operation because the injected voltage is in quadrature with the feeder current. The simulink results are been obtained through MATLAB software.

KEYWORDS: *DVR, SVC, Phase Detector, PI Controller, FLC, Sag/Swell*

I. Introduction

Sensitive loads such as medical equipment, factory automations, semiconductor-device manufacturer, and paper manufacturer are vulnerable to power-supply disturbances. Consequently, the demand for high power quality and voltage stability becomes a pressing issue. In the present power grids, voltage sags are recognized as a serious threat and a frequently occurring power-quality problem and have costly consequence such as sensitive loads tripping and production loss. Both the “Canadian Power Quality Survey” conducted by the Canadian Electrical Associate (CEA) in 1991 over 550 customer sites and the “Distribution System Power Quality Survey” conducted by the Electric Power Research Institute (EPRI) on 222 utility distribution feeders between 1993 and 1995 have shown that voltage sags are the most frequent power quality events. These disturbances occur due to, e.g., short circuits in upstream power transmission line or parallel power distribution line connected to the point of common coupling (PCC), inrush currents involved with the starting of large machines, sudden changes of load, energizing of transformers or switching operations in the grid. According to the IEEE 1959-1995 standard, voltage sag is defined as a decrease of 0.1 to 0.9 p.u. in the rms voltage at system frequency and with the duration of half a cycle to 1 min. According to the definition and nature of voltage sag, it can be found that this kind of disturbance is a transient phenomenon whose causes are classified as low- or medium-frequency transient events [2].

DVRs compensate voltage sags by injecting the proper amount of voltages in series with the supply voltage, in order to maintain the load side voltage within the specification. Typically, a DVR consists of an energy storage device and an inverter which is coupled via a series transformer to the grid. The purpose of inverter is injecting the series voltage with a controlled magnitude and phase angle to restore the quality of load voltage and avoid load tripping. The basic concept of DVR is depicted in Fig. 1. Moreover, there is a parallel switch to bypass and protect the DVR when the short circuit occurs in downstream power lines.

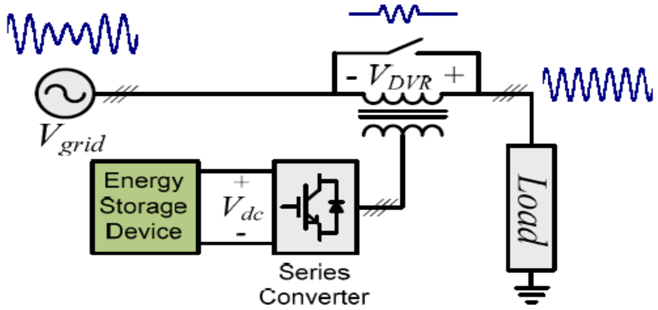

Figure 1 Principle Operation of DVR

The control system of DVR has two main parts: detection and determining the reference signal. The first one is the voltage sag detection part in which the grid voltage are measured and analyzed and based on sag detection method, the voltage disturbance can be recognized. There are different detection methods such as peak measurement, rms measurement, dq0 components measurement decoupled positive- and negative-sequence dq0 components measurement and phasor parameters estimation using Kalman filters or complex Fourier Transformation as reported in articles. The second part of DVR control system is determining the reference signal of series injected voltage. The method to determine reference signal of series injected voltage is based on the type of energy storage device, its ability to support active power and sensitivity of load to voltage disturbances. There are four basic methods of voltage compensation including in-phase, pre-sag, energy minimized and hybrid compensation methods. This paper investigates the mentioned compensation methods with detailed discussions and the comparisons to highlight their advantages and disadvantages.

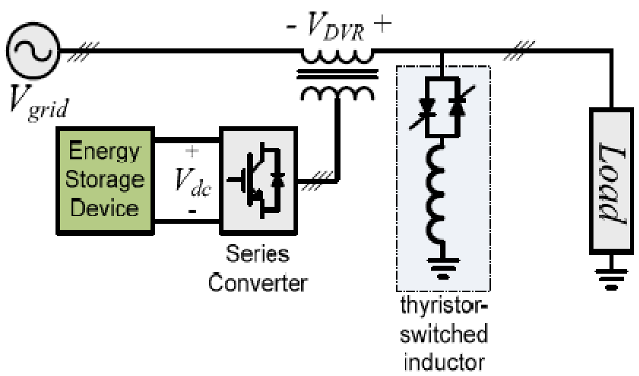

Figure 2 Schematic of DVR with shunt thyristor-switched inductor to decrease the power factor intentionally during the voltage sag.

II. Literature Survey

In order to derive a unique power quality of service index, information from both the supply network (according to standards in use) and the customer (defined in terms of load sensitivity and interruption cost) are merged. The well-known CBEMA power acceptability curve is revisited with definitions from the IEEE Standard 1159 superimposed. This depiction suggests a way to assign a cost or index of power quality events. Although individual cost assignments used in the calculation are subject to question, once the assignments are made, the calculation is consistent and gives a useful measure of quality of service. The method is illustrated factoring severity of the events based on the CBEMA curve and IEEE 1159 classified power quality events. [1]

The protection of the sensitive but unbalanced and/or non-linear loads from sag/swell, distortion and unbalance in supply voltage is achieved economically using a dynamic voltage restorer (DVR). A simple generalized algorithm for the generation of instantaneous reference compensating voltages for controlling DVR, based on basic SRF theory has been developed. This novel algorithm makes use of fundamental positive sequence phase voltages extracted by sensing only two unbalanced and/or distorted line voltages. The algorithm is general enough to handle linear as well as nonlinear loads. The compensating voltages when injected in series with a distribution feeder by a 3-single phase H-bridge voltage source converter (VSC) with constant switching frequency hysteresis band voltage controller, tightly regulate the voltage at load terminals against any power quality problem on the source side. A capacitor supported DVR does not need any active power during steady state operation because the injected voltage is in quadrature with the feeder current. [3]

Here it evaluates an auxiliary control strategy for downstream fault current interruption in a radial distribution line by means of a dynamic voltage restorer (DVR). The proposed controller supplements the voltage-sag compensation control of the DVR. It does not require phase-locked loop and independently controls the magnitude and phase angle of the injected voltage for each phase. Fast least error squares digital filters are used to estimate the magnitude and phase of the measured voltages and effectively reduce the impacts of noise, harmonics, and disturbances on the estimated phasor parameters, and this enables effective fault current interrupting even under arcing fault conditions. The results of the simulation studies performed in the PSCAD/EMTDC software environment indicate that the proposed control scheme: 1) can limit the fault current to less than the nominal load current and restore the point of common coupling voltage within 10 ms; 2) can interrupt the fault current in less than two cycles; 3) limits the dc-link voltage rise and, thus, has no restrictions on the duration of fault current interruption; 4) performs satisfactorily even under arcing fault conditions; and 5) can interrupt the fault current under low dc-link voltage conditions. [4]

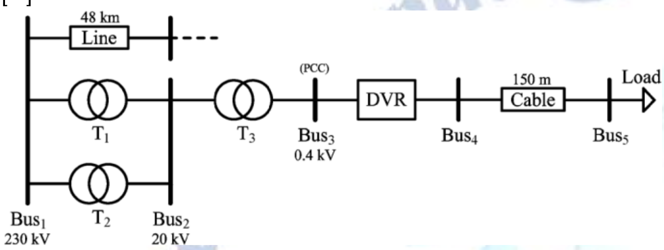

Figure 3 Single-line diagram of the system used for simulation studies

In this, it deals with a dynamic voltage restorer (DVR), or a voltage-sag compensator, which consists of a set of series and shunt converters connected back-to-back, three series transformers and a dc capacitor installed on the common dc link. The DVR is characterized by installing the series converter on the source side and the shunt converter on the load side. This system configuration allows the use of an extremely small dc capacitor intended for smoothing the common dc-link voltage. This paper provides a design procedure of the dc capacitor under a voltage-sag condition and proposes a control method for the series converter, which is capable of reducing the voltage ratings of both the series converter and the series transformers. [6]

In this paper, two new topologies are proposed for three-phase dynamic voltage restorers (DVRs). These topologies are based on direct converters. The proposed topologies do not require dc-link energy storage elements. As a result, they have less volume, weight, and cost. They can also compensate long-time voltage sags and swells. The proposed DVRs can compensate several types of disturbances, such as voltage sags, swells, unbalances, harmonics, and flickers. Moreover, due to the fact that the compensation voltage for each phase is taken from all three phases, the proposed topologies can compensate one-phase outages. In the proposed topologies, three independent three-phase to single-phase direct converters are used. Each converter operates independently and, as a result, the proposed DVRs properly compensate unbalanced voltage sags and swells. The used converters can be constructed by four or six power switches. Depending on the structure of the used converters, the compensation ranges will be different. A new control method is also proposed for using direct ac/ac converters. [7]

III. Methodology

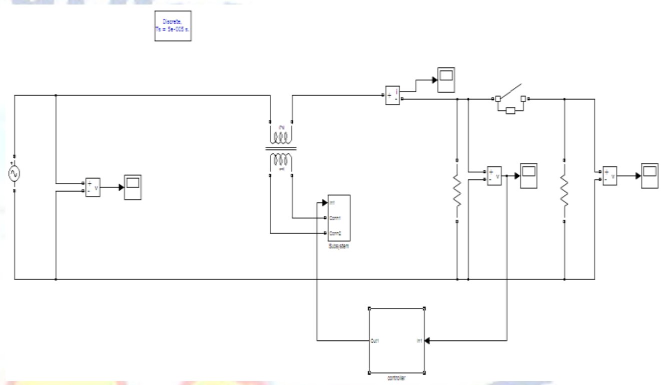

Figure 4 Schematic Diagram of Simulink Model

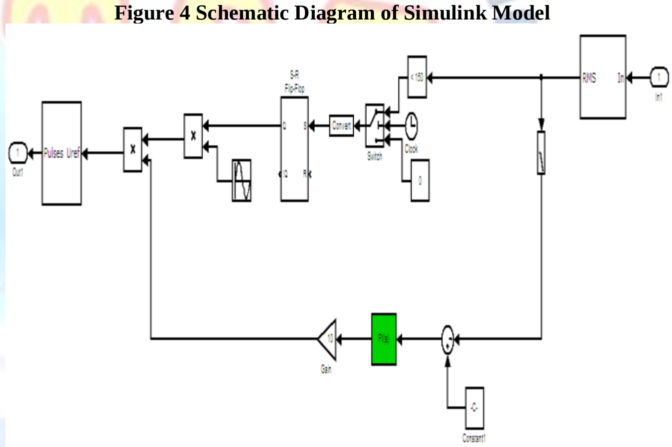

Figure 5 Control System using PI Controller

A basic FLC system structure, which consists of the knowledge base, the inference mechanism, the fuzzification interface, and the de-fuzzification interface, is shown in Fig. 3. Essentially, the fuzzy controller can be viewed as an artificial decision maker that operates in a closed-loop system in real time. It grabs plant output $y(t)$, compares it to the desired input $r(t)$, and then decides what the plant input (or controller output) $u(t)$ should be to assure the requested performance. The inputs and outputs are "crisp". The fuzzification block converts the crisp inputs to fuzzy sets, and the de-fuzzification block returns these fuzzy conclusions back into the crisp outputs. Inference engine using if-then type fuzzy rules converts the fuzzy input to the fuzzy output.

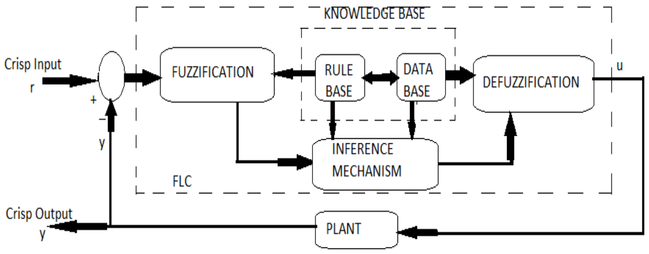

Figure 6 Basic Control System of FLC

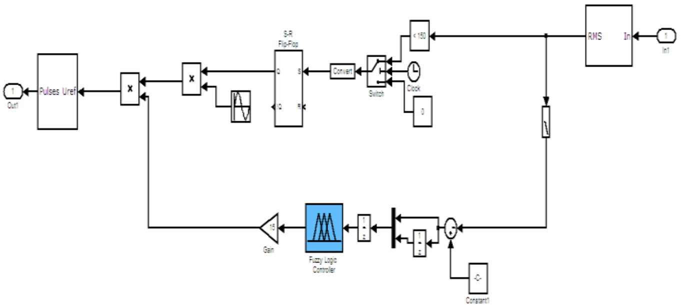

Figure 7 Control System using FLC

IV. EXPERIMENTAL RESULTS

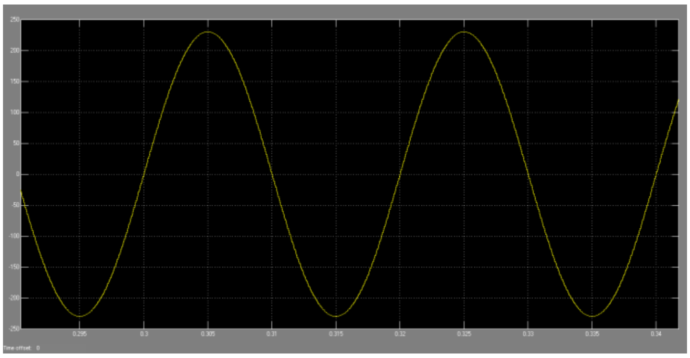

Figure 8 Input Voltage Waveform of 230V

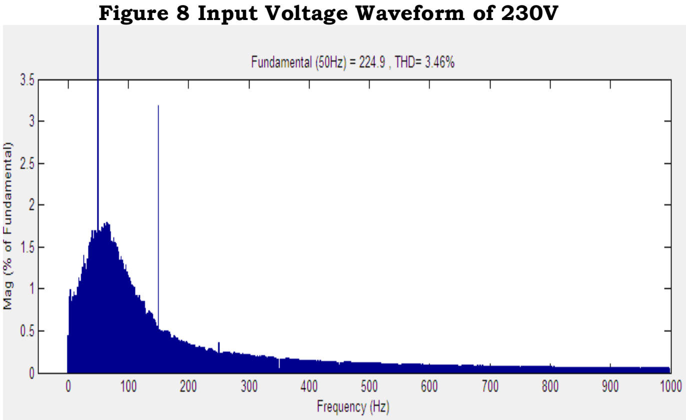

Figure 9 THD (3.46%) using Single Load through PI Controller

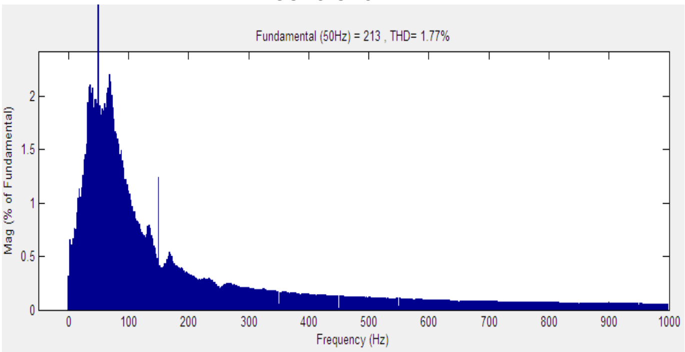

Figure 10 THD (1.77%) using Single Load through FLC

V. CONCLUSION & FUTURE ASPECTS

The Sag/Swell has been compensated through DVR using PI Controller as well as using Fuzzy Logic Controller. The results of the Fuzzy Logic are obtained better when compared to the results of PI Controller. So, therefore Fuzzy Logic Controller is been proved as the better way to proceed for the DVR topology as the THD of 1.77% is being obtained through it.

In future, the output can also be obtained using multiple loads.

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