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Power Quality Improvement in Distribution System Using Non-Conventional Energy Storage system DVR

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Abstract: *Power quality is one of major concerns in the present era. It has become important, with the introduction of industrial devices, whose performance is very sensitive to the power quality that results in a failure of user equipment's. Voltage sag is one of power quality problem which is caused by industrial device like as induction motor. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. The paper analyses and to mitigate voltage sag caused by starting of induction motor using without energy storage system DVR with PWM controller. A test system is simulated in Matlab/Simulink to prove the effectiveness of proposed control strategy with DVR.*

Keywords- *Dynamic voltage restorer, voltage sags, Hysteresis controller, power quality.*

I. INTRODUCTION

The word power quality may be defined as "analysis, measurement and improvement of bus voltage" to maintain that voltage at specified potential quantity & amplitude of current Or Frequency [2]. Institute of Electronics and electrical engineers (IEEE) standard IEEE 1100 defines power quality "as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment" [3].

As a general statement, any deviation from normal voltage quantity of a voltage source (either DC or AC) can be classified as a power quality issue. Power quality is a very important issue due to its impact on electricity suppliers, equipment manufactures and customers. Power quality issue is described as the variation of voltage, current and frequency in a power system [4].

Power Quality problems encompass a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions [5]. Distribution system is mainly affected by voltage sag and swell power quality issue. Short circuits, lightning strokes, faults and inrush currents are the causes of voltage sags. Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers, single line to ground fault on the system lead to voltage swells. Voltage sag is a decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute. Voltage swells are momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds [6]. IEEE519-1992 and IEEE 1159-1995 describe the voltage
sags/swells as shown in Figure 1.

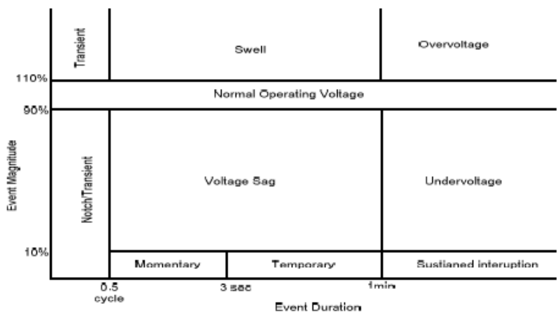

Fig 1. Voltage reduction standard of IEEE 1159-1995 [14]

There are many different methods to mitigate voltage sags and swells, but the use of a custom power device is considered to be the most efficient method. The concept of custom power was introduced by N.G.Hingorani in 1995. Like Flexible AC Transmission Systems (FACTS) for transmission systems pertains to the use of power electronics controllers in distribution system, especially, to deal with various power quality problems.

Just as FACTS improves the power transfer capabilities and stability margins, custom power makes sure customers get pre-specified quality and reliability of supply[7]. One of the most important custom power devices that has been created to improve the performance of power quality is Dynamic Voltage Restorer (DVR). The DVR maintains the load voltage at a nominal magnitude and phase by compensating the voltage sag/swell, voltage unbalance and voltage harmonics presented at the point of common coupling (PCC). These systems are able to compensate voltage sags by inserting the appropriate voltages in series with the supply voltage at PCC and therefore prevent loss of power.

II. DVR STRUCTURE

DYNAMIC VOLTAGE RESTORER

First Dynamic voltage restorer was built in U.S by Westinghouse for the Electric Power Research Institute (EPRI), and first installed in 1996 on Duke Power Company grid system to protect an automated yarn manufacturing and weaving factory [8].
The basic principle of a DVR is simple: by inserting a voltage of desired magnitude and frequency, in order to restore the load-side voltage balanced and sinusoidal [9]. This method uses real power in order to inject the faulted supply voltages and is commonly known as the Dynamic Voltage Restorer [10]. In addition to voltage sags and swells compensation, DVR can also added other features such as: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations [11].Fig 2 shows the operation of DVR.

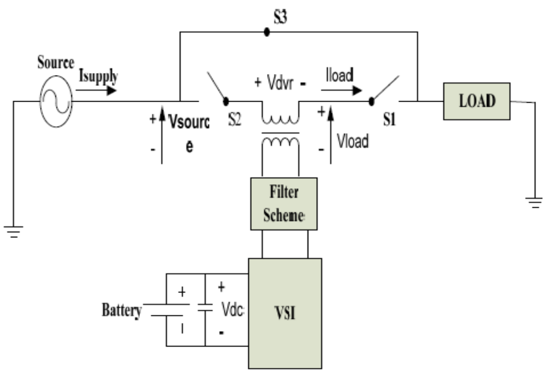

Fig 2: Operation of DVR[10]

The location of DVR is either at the MV distribution level or at the LV-level close to a LV customer [9]. Fig [3] shows location of dynamic voltage restrorer (DVR)

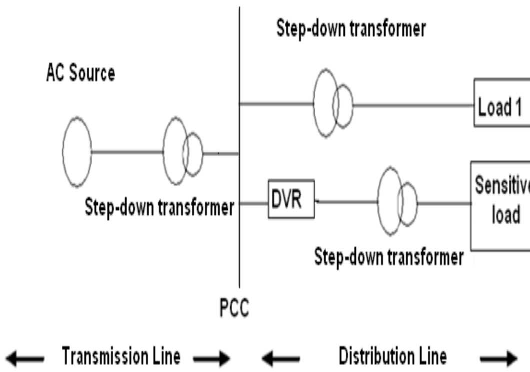

Fig 3: Location of dynamic voltage restorer DVR [4]

The DVR has two modes of operationwhich are: standby mode and boost mode. Instandby mode (*VDVR*=0), the booster transformer's low voltage winding is shorted through the converter. No switching of semiconductors occurs in this mode of operation and the full load current will pass through the transformer primary. Therefore, only the comparatively low conduction losses of the semiconductors in this current loop contribute to the losses. The DVR will be most of the time in this mode. In the injection/boost mode (*VDVR*>0), the DVR is injecting a compensating voltage through the booster transformer after the detection in supply voltage [4] [13].

III. REQUIREMENTS OF DVR

DVR mainly consist folly component**:**

- Voltage storage Converter
- Harmonic Filter
- Voltage Injection Transformer
- Capacitor
- Control System
- Non conventional energy source

A. An injection transformer/ booster transformer**:**
Its basic function is to step up the ac low voltage supplied by the VSI to the required voltage. It is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to secondary [7]. It is always connected in series with load.

B. Voltage Source Inverter (VSC)

A VSC is a power device which consista storage device and switching devices. It generates a sinusoidal voltage at any desired frequency, magnitude, and phase angle. The inverter switches are normally fired using a hysteresis controlled scheme. The hysteresis controller generates sinusoidal signals by comparing a sinusoidal wave with a saw tooth wave and sending appropriate signals to the inverter switches. Usually the rating of

VSI is low voltage and high current due to the use of injection transformer.

C. Harmonic Filter

Harmonic filter consists of an inductor and capacitor. The main task of the harmonic filter is to keep the harmonic voltage content generated by the voltage source converters (VSC) below the permissible level. (i.e.) eliminate high-frequency switching harmonics) [4]. The rating of harmonic filter is generally very small approximately 2% of the load connected to secondary winding of injection transformer.

D. Control System

The control process generally consists of hardware with programmable logic. In past it consists of Digital Signal Processing boards which provide controls like detection and correction [1]. In this unit load voltage is compared with reference voltage and then it is transmitted to sequence analyzer. Here we using a hysteresis control technique.

E. Non conventional energy source

Renewable energy sources also called non-conventional energy, are sources that are continuously replenished by natural processes. For example, solar energy, wind energy, bio-energy -bio-fuels grown sustain ably), hydropower etc., are some of the examples of renewable energy sources.

Renewable energy utilization status in the world [16]

Hydro	Wind	Solar	Geothermal	World Status
Canada	Germany	Japan	US	1
US	US	Germany	Philippines	2
Brazil	Spain	Italy	US	3
China	Denmark	Mexico	India	4
Russia	India	Indonesia	Australia	5

- Solar energy

Utility of solar energy i.e. non-conventional energy is the only alternative solution to reduce the pollution created by fossil fuels. By thermonuclear processes the sun produces huge amount of energy. This process produced heat and electromagnetic radiations [17].

Solar energy of two types
a) Solar heating
b) Solar electricity

Solar electricity is mainly produced by using photovoltaic cell which are made of semiconductor-material that convert sunlight into electricity. The sun does not provide constant energy at any spot on the earth [17]. Therefore solar cells are used to charge battery which is a secondary source of supply in DVR structure which is represented by this paper.

IV. TOPOLOGIES of DVR

There are no. of topologies for DVR. For the problem under our consideration, this paper only considers two typical system configurations as shown in Fig. 5.

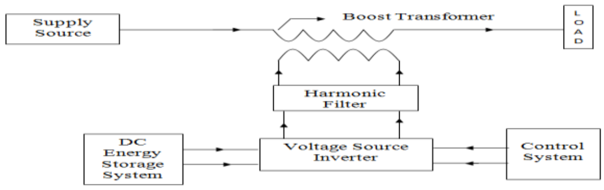

Fig 4(a): DVR with energy storage system

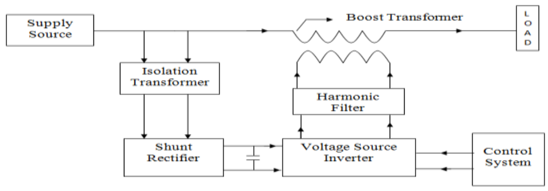

Fig 4(b): DVR without energy storage system

The topology of a DVR with energy storage is shown in Fig.4(a). In this case DC supply is strong enough to keep constant DC voltage. There are several methods to provide DC energy such as SMES, batteries, or super capacitors, which can be used in a DVR by adding a separate high-power-rating converter to the system [18]. The topology of a DVR without DC storage is shown in Fig. 4(b). DVR topologies with no energy storage use the fact that a significant part of the source voltage continuous maintain during the disturbances, and this source can be used to provide the boost energy required to maintain full power at its nominal voltage [10].

V. Hysteresis Voltage Control Technique

There are two main task of control technique in DVR
a) Detection of power quality problems
b) Generation of reference voltage for injection purpose.

In this paper, Hysteresis Voltage control technique is used to control the load voltage and determine the switching signals for inverter switches [15]. The control technique applied in this paper is based on voltage error and is non linear control method [12]. Fig.5.1 shows the principles of hysteresis voltage control. It consists of a comparison between the output voltage Vo and the tolerance limits (V_H, V_L) around the reference voltage Vref.While the output voltage Vo is between upper limit V_H and lower limit V_L, no switching occurs and when the output voltage crosses to pass the upper limit (lower band) the output voltage is decreased (increased)[7].

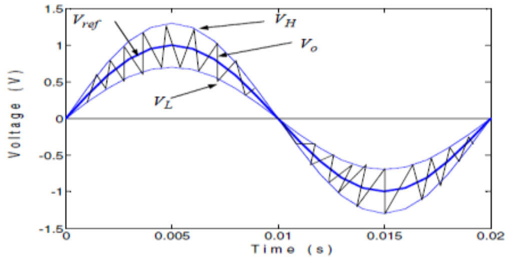

Fig 5.1 Principle of operation of hysteresis voltage controller [7]

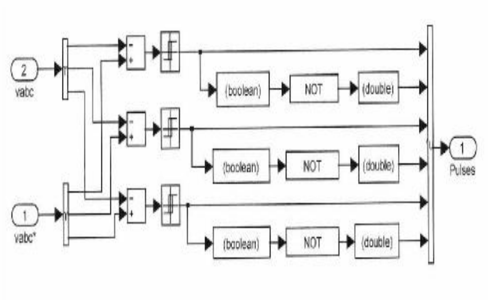

Fig 5.2 Hysteresis Controller

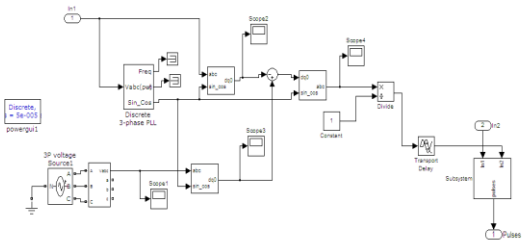

Fig 5.3 Hysteresis Voltage Control Technique

VI. Simulation and Result

6.1 *Generation of Voltage Sag Due To Induction Motor*

Simulink model of generation of sag with the help of induction motor is shown in fig 6.1. The parameter of components used in this model shown in fig table1. Fig 6.2 shows the result of Voltage sag generated by induction motor.

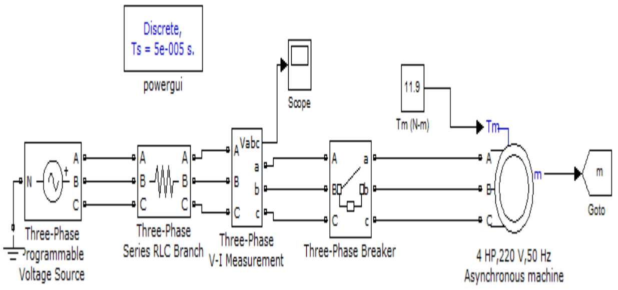

Fig 6.1: Matlab/Simulink of proposed scheme

Table1: Test System Parameter

Components	*Ratings*
Voltage Source	346 V, 50Hz
Resistance Ω	0.1Ω
Rectifier Transformer	230/230 V, 200VA
Asynchronous machine motor ratings	30 HP, 200 V,50Hz
Motor stator resistance and inductance	0.435Ω, 2mH
Motor rotor resistance and in inductance	0.816Ω, 4mH

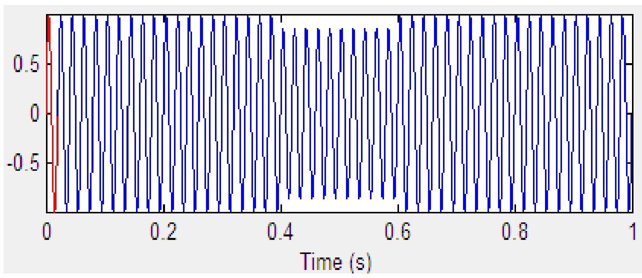

Fig 6.2: Voltage Sag

6.2*Voltage Sag compensated by second topology of DVR using Hysteresis controlled technique:*

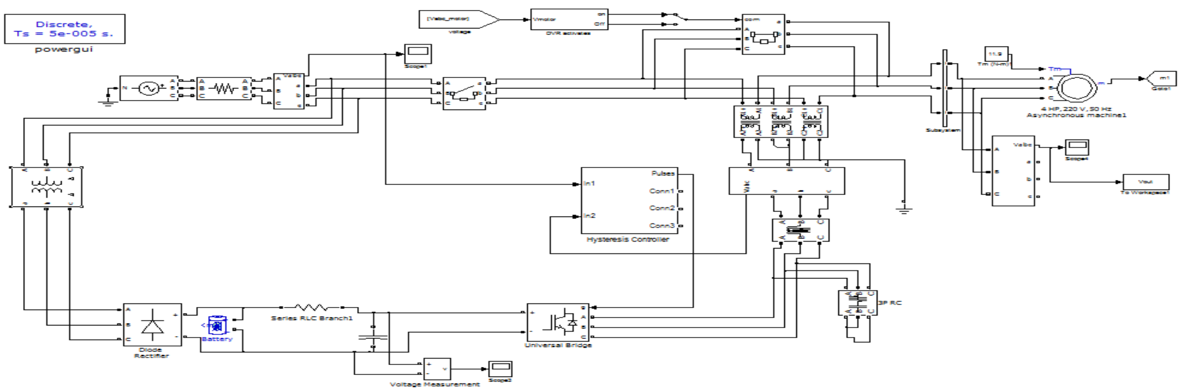

Fig 6.3: Matlab/Simulink of proposed scheme

The test system is started with voltage sag in case of starting induction motor in between 0.4 to 0.6 sec. During starting of induction motor, the motor absorb large reactive power. As the result voltage reduced voltage 1.3pu for 0.2 sec. Fig 6.4represent the load voltage after compensation of voltage sag with the help of second topology of DVR.

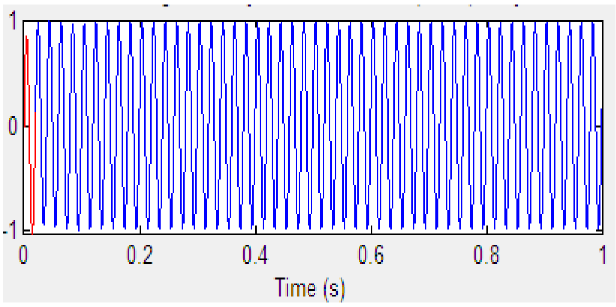

Fig 6.4: Load Voltage

VII. CONCLUSION

This paper presents a new solution for mitigating voltage sag due to the starting of three phase induction motors with the help of second topology hysteresis controlled DVR. The second topology of DVR with no energy storage use the fact that the load voltage will be maintained continuously at its nominal voltage without any disturbances in the source voltage and to provide the required boost energy to maintain full power at its nominal voltage. In this model DC supply does not required a strong energy storage system. But to reduce the variable voltage, the size of capacitor added in DC-link should be high. The simulation result also shows the better performance of DVR in comparison with previous researches using DSTATCOM because of complete compensation of sag using second topology of DVR. Also the use of hysteresis controller shows the fast dynamic response of DVR. This work can be further developed by using PI controller technique and also use another compensation technique UPQC.

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