

DVR With Fuzzy Logic Controller and Photovoltaic for Improving the Operation of wind farm

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Abstract

Wind power is one of the most important kind of renewable energies. Wind farm as a device which receives this energy needs some special conditions to work properly. The most common type of wind turbine is the variable-speed directly connected to the grid. Faults in the power system can originate the disconnection of wind farms. Dynamic voltage restore (DVR) is a custom power device used for eliminating voltage sags and swells which is the result of the faults. This paper presents a simulation model of a 12-pulse DVR using photovoltaic (PV) as a mean of providing an alternative energy source for the DVR. In this study, the design of a fuzzy logic (FL) controlled DVR are presented and extended to perform fast fault detection. A new control method for DVR is proposed by combining FL with a carrier modulated PWM inverter. Simulations were carried out using the MATLAB SIMULINK. The simulation results proved the capability of PV-based DVR in eliminating voltage sag and swell distributed system. Improving the operation of wind farm as a energy generator and stabilizing its voltage is the main result of this work.

1. Introduction

In recent years, wind power is going to be one of the most important energy among those that are used due to low cost and renewability. Wind turbine as a device that receives wind energy must work in special condition. For example the generators of turbine should have been stabilized. Thus the voltage and current of generators which connected to the bus should be steady. This process eliminates voltage harmonic and voltage sag/swell in the generators that are connected to the bus. To achieve this, the device named Dynamic Voltage Restorer (DVR) is used. This device controls the voltage of bus and removes the voltage sag/swell through fault time. So the voltage quality in generators is increased.

Design details of various DVRs are described in a lot of researches ([1] & [2]). Also, several studies on DVR control methods have been done [4]. Most researches are developed on the control strategy that uses open loop feed forward [3]. On the other hand there is another method that combine the open-loop feed forward approach and close loop feedback [4] to compensate the instability.

Recently, new fuzzy logic (FL) methods have been applied to custom power devices, especially for active power filters[5 – 7] The operation of DVR is similar to that of active power filters in that both compensators must respond very fast on the request from abruptly changing reference signals. In the literature, FL

control of DVR based on dq synchronous reference frame (SRF) is only examined in[8] .

The structure of DVR includes a DC source that can provide the power of injection. In this paper, instead of DC source connected to the DVR, the Photovoltaic (PV) have been used. PV energy is derived from a completely safe energy that is renewable and the cost is low in compare with other energies. Use this type of energy, including wind energy, due to being natural in power system, is growing day by day. Recently, several studies about the connection of Distributed Generating (DG) to the power system by the Power Electronic Systems has been done. Energy from PV is an example of DGs.

2. Power system and DVR model

Studied power system as shown in Figure 1 includes a wind turbine. Specifications and parameters of the turbine [9] is taken. Variable speed wind turbine has six 1.5 Mw generator that each of them with a capacitor bank and transformer are directly connected to the network. Wind energy converters discussed in major mechanical system is divided into two groups (wind turbine and rotor electrical) that these two parts are connected to the shaft. Gear Ratio in this model is 45 ($N_{gb} = 45$) and the number of pairs of poles is also 2. Nominal speed of the turbine is 30 rpm.

DVR is one of the important tools of power electronics. It is used to stabilize the amount of voltage in the bus of sensitive loads. The Primary work of DVR is the compensation of the voltage sag/swell. Although DVR able to do functions such as compensating harmonics, reduce the transient state of voltage and compensating of the fault. DVR includes a DC source that is by its feeding. In this paper we place the source of another source as a photovoltaic (PV) use it on the DVR model. Details are described in figure 1.

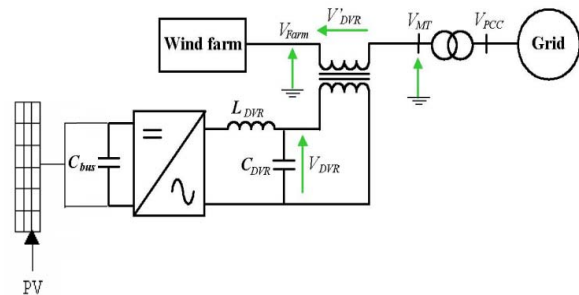


Fig.1. general system

2.1. DVR Function

DVR is used to protect sensitive electrical loads like large semiconductors, auto switches in power electronic and etc against power system disturbances. Using DVR for stabilizing the wind turbines is one of its new applications. In this paper, instead of maintaining sensitive load, protection of the variable speed generator which is sensitive to voltage changes is the main task of DVR. Recently, researches in this area are lead toward improving the behavior of wind turbines against severe disturbances [10]. DVR should provide necessary voltage to control power factor in the junction of wind turbine. It means that DVR should keep the voltage at a determined amount. In fact the reactive power compensation is the main task of DVR.

If the DVR be used for protection of load, the voltage, current and power should be remained constant in the compensation period. Figure 2 shows the compensation mode as phase diagram in two cases of absorption and injection of reactive power. compensating by reactive power absorption using DVR is shown in Figure 2-a. figure 2-b shows the compensation by injecting reactive power using DVR.

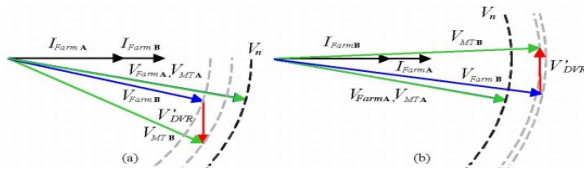


Fig.2. Reactive power compensation to control the power factor (a). Reactive power absorption, (b). reactive power injection

compensator absorbs reactive power when the lagging power factor in Pcc is obtained and wind turbine voltage is less than MT voltage. Similarly DVR injects into the network when the leading power factor in Pcc is obtained and wind turbine voltage is greater than MT voltage. The ideal case occur when the wind turbine voltage is equal to MT voltage.

2.2. DVR control

Initially, in this controlling method, in order to stabilize DC voltage and control of voltage of capacitor, the voltage of capacitor should be evaluated and compared with its basic value and the consequence of this comparison is deemed as the input for fuzzy controller 4.

In fuzzy system, input of system is defined as equations given below:

$$e(t) = v^* - v_s \quad (1)$$

$$\Delta e(t) = e(t) - e(t - 1) \quad (2)$$

v^* is reference signal and v_s is the signal to be regulated.

With regard to the Park transform, the load voltage is divided to v_d and v_q perpendicular parameters. After Park Transform v_d and v_{dref} voltages are compared and the result of the comparison is considered as input of fuzzy controller 3. This controller is utilized to stabilize the real voltage.

Parameters v_o and v_q are compared to v_{oref} And v_{qref} And the consequent is deemed as the input for fuzzy controller 1,2. Fuzzy controller 2 is used to stabilize the reactive voltage. Output of fuzzy controller 1,2,3 is given to generator pulses in order to produce switching signals, after Park inverse transform.

In this controlling method PLL is used to synchronize the injection voltage with network voltage.

Figure 3 depicts controlling block diagram of DVR system.

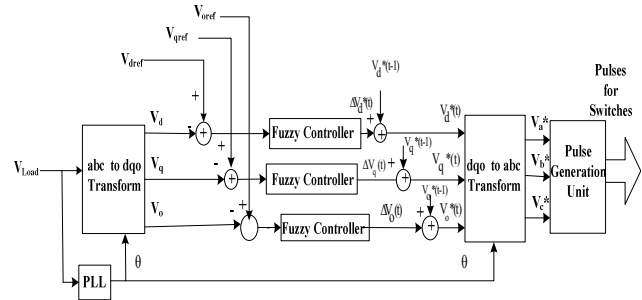


Figure .3. depicts controlling block diagram of DVR system.

Table. 1. states the laws being used in fuzzy controlling.

$e/\Delta e$	LP	SP	ZE	SN	LN
LP	PB	PM	PM	PS	Z
SP	PM	PM	PS	Z	NS
ZE	PM	PS	Z	NS	NM
SN	PS	Z	NS	NM	NM
LN	Z	NS	NM	NM	NB

2.3. PV and DC/DC converter

Photovoltaic is known as one of the perfect generators of the Dispersed Generation (DG) which use is increasing rapidly. Photovoltaic systems (PV) use massive source of solar energy and play a key role in future situation of energy sources. The reason of heavy use of photovoltaic (PV) is that it could generate a fast, clean and non-polluting power for consumer and its energy is free after installation.

Since the DC voltage produced by photovoltaic systems (PV) is fluctuated and its amplitude is small, an amplifier DC/DC converter which regulating DC voltage is necessary. DC/DC Converters should absorb the generated power of photovoltaic. So it should be designed in a way that be consistent with the ripple of current of photovoltaic system and has no interference with the positive current of PV system.[11]

In this paper, multi-input and single output (MISO) DC/DC converter for regulating and strengthening the PV system output voltage is presented and analyzed. This converter has a simple structure and its components are limited and it's cheap. The Converter topology which is used to combine and strengthen the DC output of the PV units are shown in figure (1-8).

The DVR is connected in series with transmission line. DVR is composed of a half-bridge converters for each phase that each converter has four switches. MOSFET is used in this sample. For switching each phase we need two pulses. Switching frequency is about 2KHz. Also we use an AC filter (usually a capacitor) at DVR output for removing the harmonics of switching.

In this case we use PV instead of batteries for bus DC DVR feeding which is connected to the DC capacitor. Wind turbine used in this simulation consists of six generators 1.5Mw with DFIG and the average wind speed is considered 15m/s.

for making disturbance in the circuit we use a three phase fault which is applied to the network at the time between $t = 0.05$ and $t = 0.1$.

Parameters of the power network used in the simulation are expressed in table 2.

Table 2 . Power network parameters

System frequency	50 Hz
Source voltage	25 KV
Line Impedance	$(0.605+4.84j) \Omega$
3-phase transformer	10 MVAR, 25 KV/600V
Capacitor filter	50 μ F
DC capacitor	10000 μ F
Single phase transformer	10 MVAR, 10 KV/25 KV
PV	800 KW

Parameters of wind turbine used in the simulation are expressed in table 3.

Table 3 . Wind turbine parameters

Nominal power	1.5 MW
Induction gen	600 V, 50 Hz
Air density	2.22 kg/m ³
Sweep area	176.6 m ²
$C_{p,max}$	0.411

The simulation begins with 50% voltage swell of source. figure 8 shows the network voltage in swell condition which is

occurred during the time between $t = 0.05$ and $t = 0.1$. DVR injects voltage to compensate voltage swell and wind farm voltage will remain constant. The injection voltage of DVR is shown in figure 9. Figure 10 shows the stable wind farm voltage.

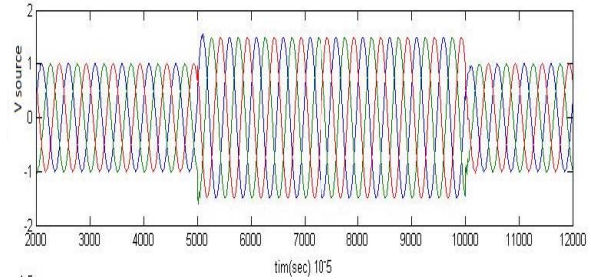


Fig.8. supply voltage in swell condition

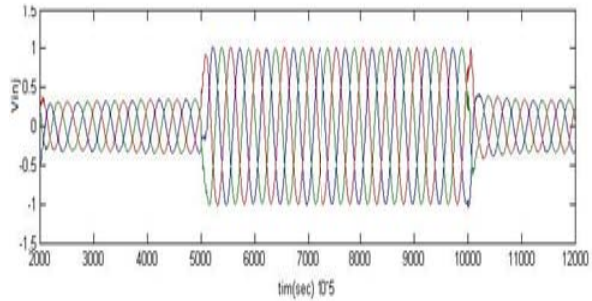


Fig.9. DVR injection voltage in swell condition

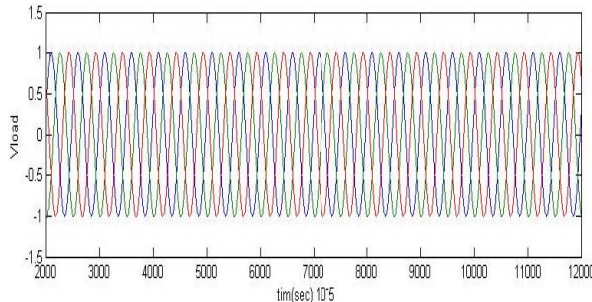


Fig.10. wind farm voltage in swell condition after compensation

After applying fault in the network between the times $t = 0.05$ and $t = 0.1$ it is seen that the network voltage drop of about 50%. In this simulation DVR cause voltage and current to be constant by injecting voltage to the network and thus the power of wind turbine become constant too. Figure 11 shows the voltage dropping of network. The injection voltage of DVR is shown in figure 12. figure 13 shows the wind farm voltage after applying fault.

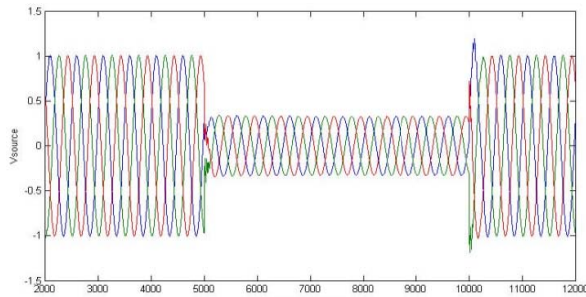


Fig.11. supply voltage in sag condition

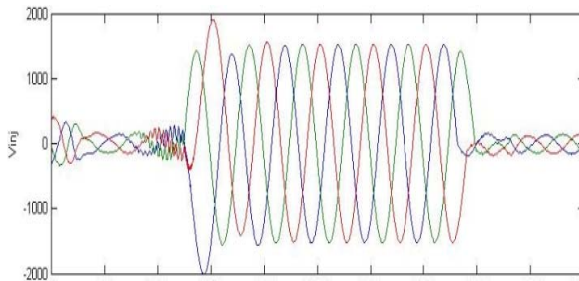


Fig.12. DVR injection voltage in sag condition

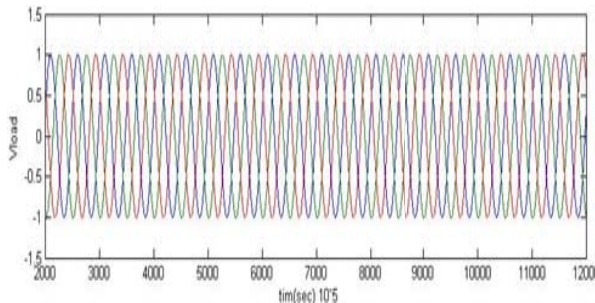


Fig.13. wind farm voltage after compensation

Terminal current of wind turbine is shown in figure 14. It is reached to stable condition after a little time.

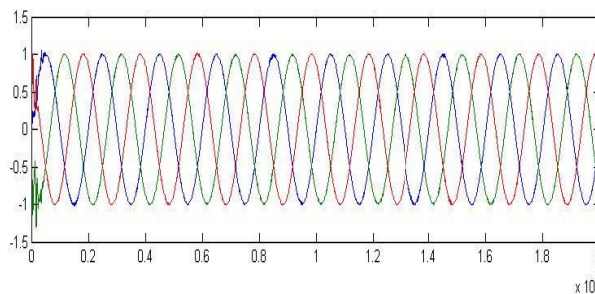


Fig.14. wind farm current after compensation (in both sag and swell condition)

4. CONCLUSION

In this paper, A 12-pulse DVR is designed and through using new control method all voltage sags and swells in the circuit is

generally compensated. In this case the terminal voltage which is connected to the wind turbine stay constant and despite the voltage instability in network wind generators will be able to remain connected to the network and work in stable condition through using DVR. In this article we could compensate a distribution systems -when sag and swell voltages occur in an accurate and controlled way. This controlling method is based on fuzzy control which is simulated by Matlab/Simulink software. Also in this paper to provide a source of DC DVR we have used PV which is a kind of natural energy source. The simulation results confirm all.

7. References

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