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POWER QUALITY IMPROVEMENT BASED ON FUEL CELL AND WIND ENERGY BASED HYBRID DYNAMIC VOLTAGE RESTORER

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ABSTRACT

In this paper we have discussed about the improvement of power quality by improving voltage profile using dynamic voltage restorer (DVR).The ultimate reason that we are interested in power quality is economic value. There are economic impacts on utilities, their customers and supplier of load equipment. It is convenient to control voltage to improve the power quality rather than controlling currents that particular load might draw. The Dynamic Voltage Restorer (DVR) is a device that detects the sag or swells and connects a voltage source in series with the supply voltage in such a way that the load voltage is kept inside the established tolerance limits. To minimize the effect of pollution on nature caused by energy production, renewable energy resources are mostly used. In this we paper we have also used wind power generation interconnected with fuel cell as the power source for Dynamic voltage restorer.

Keywords: DVR Dynamic Voltage Restorer, PWM Pulse Width Modulation, V_s Source Voltage, V_L Load Voltage, V_{DVR} Dynamic Voltage Restorer

I. INTRODUCTION

The power utilities companies have motto to supply the uninterrupted and economical power to consumer end. Distribution companies must maintain supply voltage and supply frequency at specified level, but in practical operation these quantities can't be maintained at specified level because of non linear industrial load and automated system. on linear loads causes distortion of sinusoidal waves which consequences loss of power quality. Power Quality problems results a wide range of disturbances such as voltage sags, swells, flicker, harmonics distortion, impulse transient, and interruptions. Rural location remote from power source, unbalanced load on a three phase system, switching of heavy loads, Long distance from a distribution transformer with interposed loads, unreliable grid systems Equipments not suitable for local supply are the causes of dips, sag and surges.

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Table 1: Examples of Financial Loss Due to Power Quality Incidents

Sn.	Sector	Financial loss per incident
1.	Semi-conductor production	3800000 $
2.	Financial trade	6000000 $ per hrs
3.	Computer centers	750000 $
4.	Telecommunication	30000 $ per min
5.	Steel industry	350000 $
6.	Glass industry	250000 $
7.	Offshore platform	250000-750000 $ per day

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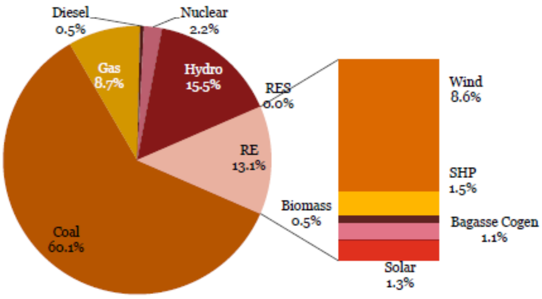
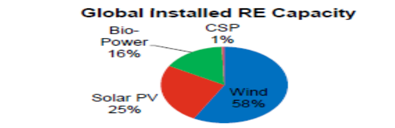
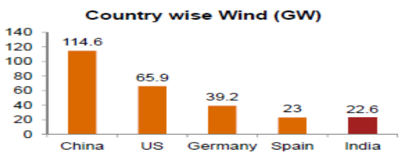


Figure-1 Present Power Scenario of India

Total installed capacity of **263.66 GW** and RE capacity of **34.35 GW** (**13%** of Installed capacity and approximately **7%** of electricity produced) *(as on March 2015)*

Wind energy is the electrical energy obtained from harnessing the wind. The specific energy costs per annual kWh decrease with the size of turbine. The wind energy potential in many developing and emerging countries is substantial. In many locations, generating electricity from wind energy presents an economically viable alternative to the use of conventional fossil energy sources such as coal or diesel. In developing and emerging countries, wind turbines are an alternative to conventional power stations. In comparison to fossil-fueled power stations, wind energy can now be cost-effective in many places, as well as being non-polluting and reducing dependence on imports of fossil fuels.





Generating electricity from the wind requires that the kinetic energy of moving air be converted to mechanical and then electrical energy, thus the engineering challenge for the wind energy industry is to design cost-effective wind turbines and power plants to perform this conversion. The amount of kinetic energy in the wind that is theoretically available for extraction increases with the cube of wind speed. However, a turbine only captures a portion of that available energy.

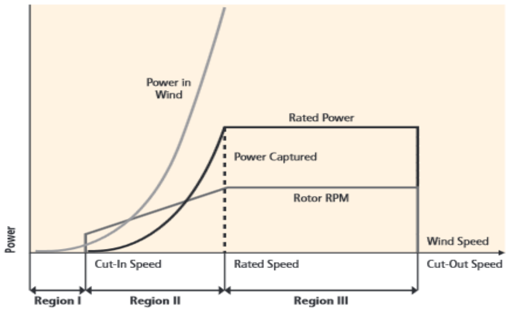


Figure-3 Conceptual Power Curve for a Modern Variable-Speed Wind Turbine

Specifically, modern large wind turbines typically employ rotors that start extracting energy from the wind at speeds of roughly 3 to 4 m/s (cut-in speed).

II. FUEL CELL

Solid oxide fuel cells (SOFCs) have potential to be the most efficient and cost-effective system for direct conversion of a wide variety of fuels to electricity. The performance and durability of SOFCs depend strongly on the microstructure and morphology of cell components.

It is a device which is used in conversion of chemical energy into electrical energy. The fuel cell consists of two electrodes known as anode and cathode.

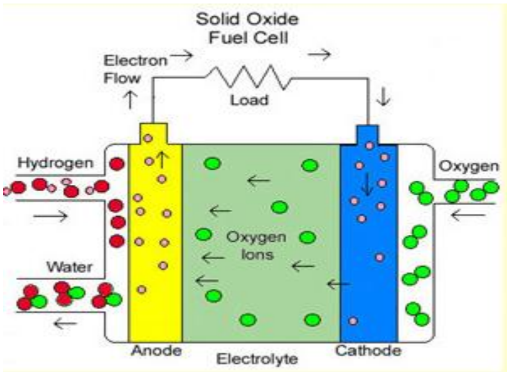


Figure-4 SOFC Fuel Cell

It uses a hard, ceramic compound of metal oxides as electrolyte. It operates at 1000 degree C and has 60% efficiency. Apart from above fuel cell are more advantageous as on the scale of efficiency, flexibility, reliability, maintenance and load performance.

III. METHODOLOGY

Dynamic voltage resotere is basically a series voltage injection technique. As shown in figure the load voltage VL will be summation of supply voltage Vs and controlled injected voltage Vinj where controlling of this injected voltage is based on the disturbance occur in the power transmission line thus the final voltage at the load end will have improved voltage profile and does not get effected by connected load.

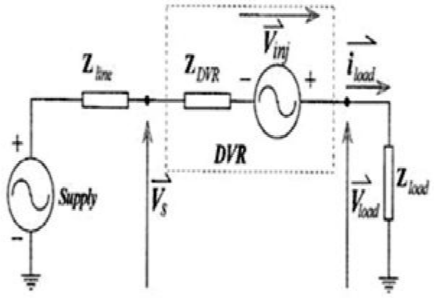


Figure-5 Conceptual View of Dynamic Voltage Restorer

Controlling of injected voltage power electronics based inverter circuit associate with filter circuit is in use. the output of this filter circuit is fed in series to the transmission line with the help of transformer. The primary side voltage of transformer is under control of switching of power electronics based switches. The switching signals for trigerring of these connected power electronics switches is based on disturbance occur in voltage due to connected loads causes change in reactive power in transmission line

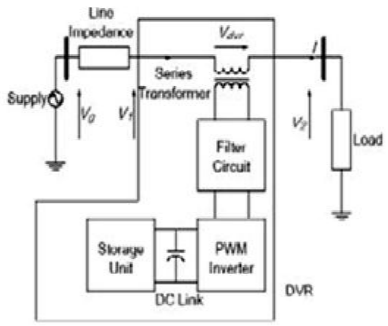


Figure-6 Block Diagram of Dynamic Voltage Restorer

The system impedance (Zth) depends on the fault level of the load bus. When the system voltage (Vth) drops, the DVR injects a series voltage VDVR through the injection transformer so that the desired load voltage magnitude VL can be maintained. The series injected voltage of the DVR can be written as

$$V_{dvr} = V_L + I_L - V_{th} \quad .....(1)$$

IV. OPERATION OF DVR

The basic function of the Dynamic Voltage Restorer is to inject a controlled voltage in series with transmission line. This generated controlled voltage by a forced commutated converter and for injection of voltage booster transformer is in use.

The amplitudes of the injected voltages are controlled in such a way to eliminate any type of voltage mismatch as an effect of reactive power mismatch due to connection of load which require heavy amount of reactive power during starting and running conditions. This means that any difference in voltages caused by transient disturbances in reactive power flow in the ac feeder will be compensated by an equivalent voltage generated by the connected converter in series and injected on the medium voltage level through the booster transformer known as dynamic voltage restorer technique for improvement of voltage as well as power quality.

The DVR has three modes of operation which are:

1. Protection mode 2. Standby mode 3. Injection/Boost mode.

Dynamic voltage restorer provide protection mode when the current on the load side exceeds a permissible limit due to any type of fault or abnormal condition, the Dynamic Voltage Restorer will be isolate itself from the systems by using the bypass switches and protect connected power electronics based switching circuit. during standby mode of operation of dynamic voltage restorer there will not any switching of power electronics based switching circuit will take place thus in this mode of operation current will passes through the winding connected through transmission line of the connected transformer and Dynamic voltage restorer do not play any role in this mode of operation in power transmission. In the Injection mode the Dynamic Voltage Restorer is compensating reactive power through the booster transformer due to the detection of a disturbance in the supply voltage thus overall voltage profile of transmission line will become constant and power quality will get improved at the load end. For injection of reactive power in transmission line Dynamic voltage restorer need some power source. this requirement of power can be fulfil by renewable energy source thus use of wind energy and fuel cell will become possible here as the power source of dynamic voltage restorer.

V. VOLTAGE INJECTION OF DYNAMIC VOLTAGE RESTORER HAVING FOUR DIFFERENT METHODS AS

i. Pre-sag compensation method ii. In-phase compensation method iii.In-phase advanced compensation method

In the pre-sag compensation method the injected active power cannot be controlled by dynamic voltage restorer and it is determined by external loading conditions such as the change in load and any type of abnormality in loading conditions. phasor diagram shows the injected voltage and its effect in load voltage pre sag method.

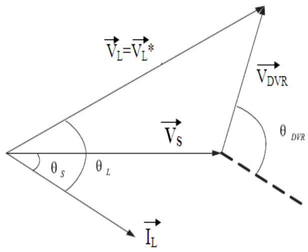


Figure-7 Pre-Sag Compensation Method

In phase compensation method the injected voltage is in phase with the supply side voltage. The most important criteria for power quality that is the constant magnitude of load voltage are satisfied in phase compensation method. As shown in figure 7 shows the phasor diagram of injected voltage and its effect at load voltage in phase compensation method.

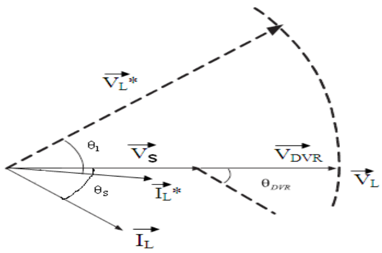


Figure- 8 In-Phase Compensation Method

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In phase advanced compensation method the real power spent by the Dynamic Voltage Restorer is decreased upto minimum by minimizing the phase angle.

In case of pre-sag and in-phase compensation method the active power is injected into the system when it require by the system as these conditions are abnormal consumption of reactive power by connected loads. The active power supply is limited stored energy in the DC links and this part is one of the most expensive parts of Dynamic Voltage Restorer. This DC link voltage can be directly fed by a dc source or any other type of renewable energy based power source. As in this paper these renewable sources are wind energy and fuel cell.

VI. SIMULATION OF DYNAMIC VOLTAGE RESTORER WITH WIND ENERGY AND FUEL CELL

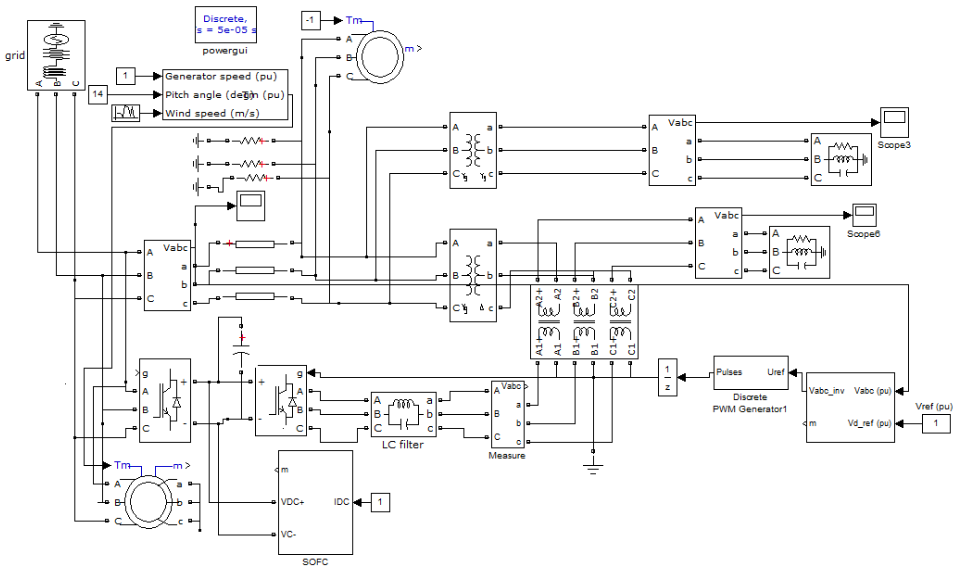

Figure- 9 Simulation of Wind Energy and Fuel cell Based Dynamic Voltage Restore

In this simulation diagram all the calculation are made on the per unit basis. The ratting of grid is 11 KV and 50Hz. connected with a transmission line having length of 400 km. which is count under long transmission line such as supply frequency of 50 Hz. Transmission line of this length is capable to generate disturbance in the voltage due to consumption of reactive power. A voltage measurement and scope are connected to get value of voltage before transmission. At the end of this power transmission a synchronous machine is connects and acts as a motor. The ratting of this connected synchronous machine is 1100V 50Hz with active power rating of 3730MW. the value of mutual inductance will rise as 1.235 to proper compensation of reactive power and generate voltage deviation in the power system. This connected synchronous machine is representing load on power system. By this connected load disturbance in the power system voltage will took place and the dynamic voltage restorer is connect. Two different voltage measuring units and scopes are connect at pre and post DVR locations to provide voltage values with waveform at these different locations. At the end of the transmission line a static load is connect where power supply will injected after been affected by the dynamic voltage restorer.

The DVR unit in this simulation diagram have an inverter which have triggering curuit based on the Pulse width modulation technique. The width of PWM is depend upon an error signal in between supply voltage and require voltage. The output of inverter is fed to the booster transformer and then to the transmission line. The input of inverter in DVR unit is a DC source. In the simulation dc supply will provide by wind energy and fuel cell. Fuel cell is capable to generate the DC voltage thus it feed directly to the DC link having connection with output of rectifier unit which rectify the output of wind energy based AC power generation by induction generator. Ratting induction generator is 440V, 50Hz and voltage ratting of connected fuel cell is same as induction generator. This fuel cell having 450 cells are connected in series with each other. The ohmic value of each cell is $3.28*10^{-4}$ ohm and electrical response time will be 0.015 sec.

VII. SIMULATION RESULT

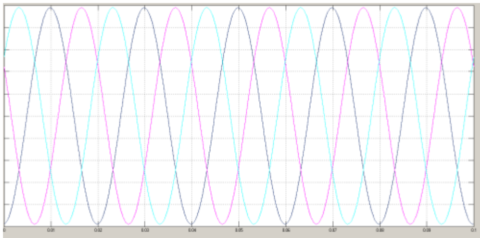

Figure-10 Shows the Supply Voltage in Case of Simple DC Supply Based DVR System

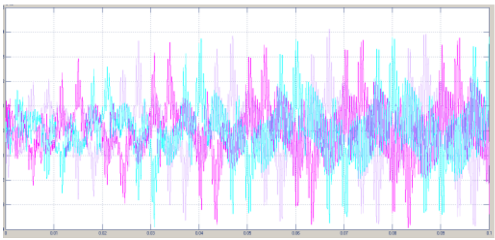

Figure-11 Voltage Get Affected by Transmission Line and Loading in Case of Simple DC Supply Based DVR System

Figure-11 shows the voltage of which get affected by transmission line and loading of the power system as it is easily observable that voltage at this point is get effected by in consistency in the reactive power flow in power transmission line. This inconsistency in reactive power by power system will be due to loading of synchronous machine.

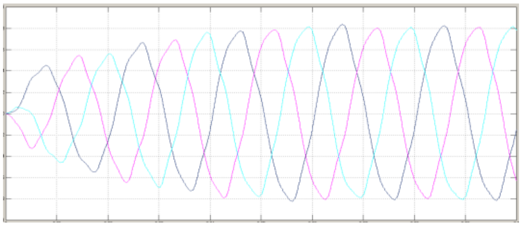

Figure-12 Voltage waveform after injection of DVR voltage

Figure-12 shows the voltage waveform after injection of DVR voltage in the main power supply transmission line with the help of booster transformer. The voltage in the power transmission line will get much improvement. This is the voltage of post location of DVR connection where DVR have DC voltage source only for supply the inverter section of DVR unit.

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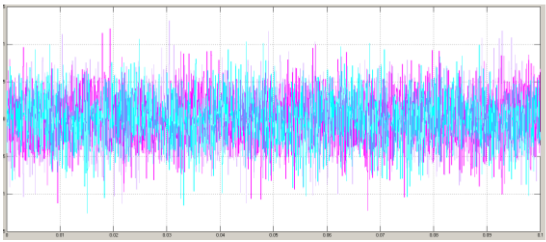

Figure-13 Voltage Get Affected by Transmission Line and Loading in Case of Wind Turbine Based DVR System

Figure-13 shows the voltage of which get affected by transmission line and loading of the power system in this case induction generator is also connect in the power system thus unbalance in reactive power will become rather more in this case thus voltage profile in this case get more deviation as shown in above figure.

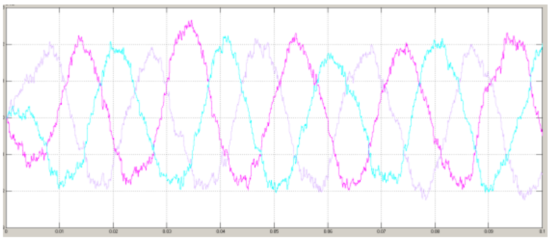

Figure-14 Voltage Waveform After Injection of Wind Turbine Based DVR System

Figure- 14 shows the voltage waveform after injection of only wind energy based DVR in the main power supply transmission line with the help of booster transformer. As improvement can be observe at this point of voltage but still some harmonics are present due to limitations of wind energy and DC link technology.

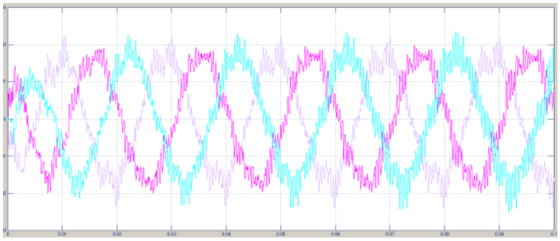

Figure-15 Voltage Get Affected by Transmission Line and Loading in Case of Wind Turbine and Fuel Cell Based DVR

Figure- 15 shows the voltage of which get affected by transmission line and loading of the power system in this case hybrid renewable system based DVR, hybrid renewable system are connect to provide source of DVR. This hybrid system consists of wind turbine based induction generator and fuel cell. As one can easily analyse that hybrid renewable system based DVR will provide better balancing of reactive power at pre location of DVR also, as the deviation in voltage is not as high as in other two cases after connection of load and transmission line.

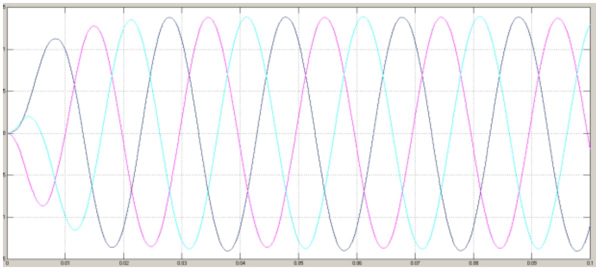

Figure-16 Voltage Waveform After Injection of Wind Turbine and Fuel Cell Based DVR System

Figure- 16 shows the voltage waveform after injection of voltage by DVR. Hybrid energy based DVR system is in use to maintain the reactive power flow and maintain voltage after it been disturbed by connection of load. As one can easily observe that improvement in the voltage is maximum when wind energy and fuel cell based hybrid system is in use to provide energy source for DVR. Apart from the improvement in voltage wave from the time taken for improvement of voltage is also reduces by using hybrid DVR system, as shown in given table

Table 2 Comparison Between Times Taken to Improve Voltage in Different DVR System

SN.	Source of DVR	Time taken for improvement of voltage
1.	DC voltage source	0.048 sec
2.	Wind energy after rectification	0.036 sec
3.	Fuel cell and wind energy based hybrid system	0.017 sec

Thus form the above table it is clear that use of hybrid energy based DVR system will improve the voltage profile and also the time taken for improvement in deviation in voltage will also get improved.

VIII. CONCLUSION

As the above result shows that use of DVR will improve the voltage profile on the basis of magnitude and frequency. Thus by maintaining the voltage within a certain range of variation will be the insurance of power quality of the power system. By application of wind energy and fuel cell based DVR system the overall voltage profile will get improved even use of this hybrid system based DVR will use lesser time to improve voltage profile. Thus it can be conclude that use of hybrid system as a energy source of DVR will have much improve performance as compare of other two type of DVR system. Power quality under this hybrid energy based DVR operation will get much improved.

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