An Autonomous Res Based System to Improve Power Quality Using DVR With ANN Controller Technique

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Abstract

Presently, power quality issues are the most important problems arising in various sectors. As a result of this it needs urgent compensation to get good quality of power. The difficulties such as drop and rise in voltage, voltage flickering etc makes the system weakened and it decreases the load voltage. Therefore load compensation is necessary and also the power quality should be improved. The proposed topology identifies and compensates the problems of drop and rise in voltage using a FACTS device named Dynamic Voltage Restorer. This technique is one among the best method to compensate the drop and rise in voltage and used in both low voltage and medium voltage applications. Based on the hybrid

Keywords: Load Compensation, Dynamic Voltage Restorer, Artificial Neural Network, Voltage sag, Voltage swell, Voltage Flicker.

1 Introduction

The most important difficulty faced now a days in our electrical scenario is power quality. The usage of electronic, power electronic, programmable logic controller equipments causes complete changes in the nature of electrical output. Due to this origination of power quality issues arises and this makes the variation in the voltage waveform. Because of this most of the industrial, residential and information technology services experienced certain crucial situations related with power quality and in some events their profit margins of several activities also decreased. The power
quality definition states that the electrical load driven by the electrical power and the load’s capability is to perform correctly. The electricity is generated, transmitted and distributed through the transmission cable until it reaches the load centre. At the time of transferring electricity from the generating to delivering point it should be compromised with several factors such as weather, demand etc for providing good quality of power supply. Different types of power quality drawbacks are voltage spikes, voltage dips, under voltages, high-voltage spikes, frequency variation, power sag, blackouts, brownouts etc. Energy storage devices are used to increase the power thereby solving the power quality issues. One of the power enhancement device used in this proposed work is dynamic voltage restorer [1].

Power usage demand is increased currently because of the high population but simultaneously the generation, transmission and utilization cost, scarcity of fossil fuels also increases. Therefore the production of power is a difficult task and the power promoter neglect to reduce the cost of power. Considering these situations consumers thought of finding alternate solution for getting good quality of power and the reduction of cost. Compromising these two factors they found of implementing a combinational power system with the interconnection of sustainable energy sources. This system can be connected in the utility grid and works under two modes. One is islanded mode then the other one is grid connected mode. Utility grid produces more power when compared to the power generation industry. Hence where ever more power is required hybrid energy system can be connected. Certain problems such as safety, synchronization, power quality and load sharing etc arises due to grid integration but this can be overcome by power quality mitigation techniques[2].

Using the power electronic devices, quality issues occur. So consider these matters at the time of planning the design of power system. FACTS technology is introduced for the enhancement to get more better quality of power to avoid the drawbacks analyzed by the use of power electronic devices. To manage the real power flow of voltage and reactive power flow of voltage the FACTS concept was originated in the network of transmission line. It is a power electronic depended system along with several controllers are connected to rise the power flow, to give control for ac transmission system, to regulate the bus voltage etc thereby developing the power transfer capability, stability and small system losses. This paper combines the hybrid energy system with a FACTS device namely DVR. DVR is also known as static synchronous series compensator. This device is mainly used for balancing the voltage quality problems [3].

2 Related Works

A detailed literature survey are available regarding the power quality issues are stated. [4] This paper proposes the possible solution for the power quality issue arisen from the grid integration. Back propagation control algorithm along with DSTATCOM are used to increase the power quality by eliminating the harmonics, power factor correction, load balancing etc are proposed[5]. [6] proposed to achieve better quality of power with one directional ac-dc boost converter. An electrical power system operation can be considered with certain comparison of FACTS devices [7]. Interface of distributed generation system with active filter modeling was done [8],[9] Double tuned parallel resonant circuit was suggested to achieve better quality of power and efficiency. A new control algorithm was designed for the DVR to manage the voltage dip and swell in the transmission lines [10]. SVPWM implementation in DVR was studied and analyzed through PSCAD software[11]. [12] suggested a two level DVR to control current using a repetitive controller.[13] Maximum benefits achieved from the grid
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integration of 3 phase 4 wire systems. [14] paper focuses on the fuzzy control technique used for the DVR. Neural network technique used for the unified power quality control with ANN algorithm [15]. To reduce the low voltage sag and swell problems DVR is recommended [16]. [18] Better power quality can be achieved with new control strategy of fuzzy logic controller was adopted in the DVR with PLL technique. [19] focused as a review paper on the custom power devices when integrated with renewable energy sources for the better achievement of power quality. [20] paper focused on the combination of solar battery, wind with DVR to attain better power quality. Simulation of solar panel with MPPT technique using ANN algorithm was simulated to obtain better power quality results [21]. An autonomous PV residential systems are designed to produce better power quality [22]. DVR using cascaded multilevel converter was designed to keep the load voltage with in certain limits [23]. A detailed study of DVR and its components, functions were described [24]. [25] focused on the incorporation of STATCOM with DVR to manage the voltage and harmonics produced. Hybrid solar and wind system with MPPT and DSTATCOM technique to improve power quality [26]. For the development of power quality smart grid inverters are incorporated in the distribution networks [27].

In this work, wind and diesel engine is incorporated with the grid system. When the power distribution from the wind gets suddenly terminated due to natural disasters or overload, then automatically the diesel engine will be activated and transmits the required power to the utility grid. Solar PV systems are used as a backup source for the ANN based DVR to supply the necessary power when required also to maintain sufficient power at the utility. Simulation for the Implementation of wind, diesel and PV based DVR of the proposed system were simulated using MATLAB software also the comparative outputs shown for better power quality using different controller techniques.

3 Proposed System

This proposed system works as an autonomous system in which it consists of wind and diesel engine as a main source whereas diesel engine has a battery backup. The output from the wind and diesel is ac and a converter converts this ac supply into dc. While transmitting ac power from the wind system towards the distribution side, due to external disturbance, increase in voltage etc, the wind power is disconnected and then the diesel engine is switched on automatically by the automatic selector switch. Now the continuation of power is transmitted from the diesel engine to the utility grid. While transmitting the power if any interruption happened because of frequency change, voltage sag, voltage swell etc, at a particular interval in order to compensate these power quality issues a FACTS device named DVR (Dynamic Voltage Restorer) is included in the system. DVR is based on ANN controller and it uses an solar photovoltaic system as a back up source. This solar back up supports the DVR for the proper maintenance of power supply to the utility grid. Therefore the power quality is improved using this autonomous hybrid system.
4 Basic Modules of Hybrid Systems

4.1 Wind Power Generating System

To increase the system efficiency and to get steady energy supply two or more renewable sources are incorporated in hybrid systems. Wind system converts the kinetic energy to mechanical energy and also to convert mechanical to electrical energy. Depends upon the rotor construction and blade design the wind power is evaluated\cite{28}.

The wind power flows through the air is expressed as,

\[
P_{air} = \frac{1}{2} \text{(air mass per unit volume)}^2
\]

\[
= \frac{1}{2}(\rho A V_\infty^2)(V_\infty)^2
\]

\[
= \frac{1}{2}\rho A V_\infty^3
\]

\[P_{air} - \text{Wind power in (w), A - area measured in (m}^2) , V_\infty \text{ denotes the wind velocity}
\]

Even though the equation (1.1) provides the wind power, the power coefficient makes the power to reduce when it moves towards the wind turbine rotor. Therefore \(C_p\) is given by,

\[
C_p = \frac{P_{wind \, turbine}}{P_{air}}
\]

\[
P_{wind \, turbine} = C_p \times P_{air}
\]

\[
= \frac{1}{2}\rho A V_\infty^3
\]
To attain the maximum efficiency and power factor PMSG coupled with wind turbine runs under small speed condition and also the gear box arrangements are not required when this is compared with other generators.

4.2 Diesel Engine System

As an electrical point of view diesel generator act as a prime mover and generator. Diesel engine is incorporated in a hybrid energy system when there is no sufficient amount of output from the renewable energy sources. IC engines produces mechanical energy as output as well as generator produces electrical energy as output. It is also easy to buy because of their size, initial cost, and simplicity. Due to some technical problems there might be any short falls in power production or a power failure occurs then the usage of diesel generator was well satisfactory in supplying power to the utility grid.

4.3 Solar Photovoltaic (PV) System

The photoelectric effect from the solar pv system yields the electricity\cite{20}. A PV array contains the series-parallel combination of pv cells. Figure 2 represents the basic circuit of PV cell.

![Figure 2. PV cell equivalent circuit](image)

Equation (1.6) & (1.7) shows the mathematical model of PV array.

\[
V_{pv} = \frac{nKT}{q\ln \left(\frac{I_{sc}}{I_{pv}} + 1\right)} \quad 1.6
\]

\[
I_{pv} = I_{sc} - I_{pvo} \left[ \exp \left( \frac{q(V_{pv} + I_{pv}R_s)}{N_sKT_{n}} \right) - 1 \right] - \frac{V_{pv} + I_{sc}R_s}{R_{sh}} \quad 1.7
\]

Where PV current as \( I_{pv} \), PV voltage as \( V_{pv} \), K gives the Boltzmann constant, Reference temperature of pv cell as \( T \), Short circuit current as \( I_{sc} \), Saturated diode current as \( I_{pvo} \), Electronic charge referred in coulombs as \( q \), Number of cells combined in series as \( N_s \), Series and Shunt resistance as \( R_s, R_{sh} \), Diode ideality factor as \( n \).

Considering this proposed system, to support the DVR solar PV system will act as a back up source for providing necessary power required for the compensation of load also for rectifying power quality issues risen at a particular interval.
4.4 Dynamic Voltage Restorer

In our modern world electricity is one of the key factor at the same time we should worry about the quality services offered to us. Therefore in the real scenario power quality is one of the major factor considered. Power quality problems arises in various faulty situations. Some of the issues arises due to the factor voltage are drop/rise in voltage, stability, discontinuity and noise. This fault may cause from the apparatus tripping, commercial shutdown, industrial, domestic component and improper working of drive system. DVR is the only FACTS device which gives the accurate solution for the power quality problems by providing necessary voltage quality service. It is found out in the new modern era and used for the removal of power related factors[17]. Fig.3 shows the basic structure of DVR.

![Figure 3. Basic structural model of DVR](image)

DVR contains an (i) energy storage unit which stores energy in DC form and gives real power for the DVR. (ii) To assure the dc input voltage fed to the inverter a capacitor is used. (iii) Inverter converts dc to ac and a step up transformer with VSI is used. (iv) For the conversion of inverted PWM waveform into a sinusoidal waveform passive filters were used. Also filter eliminates the harmonics generated by VSI. (V) By pass switch will secure the inverter from rise in current during any fault occurrence. (vi) An voltage injection transformer with One 3-φ transformer units or three 1-φ phase transformer units used for injecting voltage in a three phase system. Fig.4 shows the block representation of DVR with solar back up.

![Figure 4. DVR Block representation with solar as energy storage device](image)

DVR connects the transmission line in series through the voltage source converter and transformer. Whenever voltage varies under loaded condition DVR is used to keep the voltage stable. Even if there is a change in load and voltage sag etc it
put back the voltage in the distribution system. Therefore it is named as customer power device[20].

4.5 Artificial Neural Network

In the present criteria neutral networks plays an important role.[29] Maximum Power is tracked from the solar system using MPPT technique. Different types of algorithms and controllers were suggested to find the maximum power but this ANN algorithm is one of the accurate algorithm used because of the good efficiency and reduction in tracking time. ANN is a mathematical model with the algorithm based on neural network, in which the structure and function depends on biological neural networks. Application such as manufacturing, medicine, sports, renewable energy etc, Various types of architectures are used in neural networks and it is a forward monitoring network. i.e, information will flow in same direction where they are connected. Lastly from the input layer the information is pass over to the hidden layer and then it flows to the output layer.

![Basic Artificial Neural Network Diagram](image)

5 Simulation Results and Discussion

In this paper simulation results for the hybrid energy system which is combined with the DVR and ANN controller are presented. PID controller and ANN controller were compared for the parameters of wind voltage and current, engine voltage and current, load voltage and current, Grid voltage and current, Source voltage with sag and swell compared for load voltage and load current, real and reactive power for wind, diesel and load were presented. THD of the restored voltage using PID, GOA, fuzzy and ANN were simulated and tabulated. Simulation results are presented to enhance the developed models and for controlling the proposed DVR system.
Figure 6. Overall Simulation Diagram using DVR with ANN controller

Real and Reactive power for wind, diesel, load

(a)

Wind Voltage and Wind Current

(b)
Engine-voltage output and Engine-current output

(c) Load-voltage output and Load-current output

(d) Grid-voltage output and Grid-current output

(e) Sag and swell output compared with load-voltage
Figure 7. Restoration of voltage outputs for PID controller and ANN controller obtained from simulation. (a) Real and Reactive power for Wind, Diesel engine and Load (b) Wind- voltage and current output (c) Engine- voltage output and Engine-current output (d) Load- voltage output and Load-current output (e) Grid- voltage output and Grid-current output (f) Voltage sag and swell compare with load voltage and load current.

6 Comparative Analysis

THD of the Restored Voltage Using PID

THD of the Restored Voltage Using GOA
THD of the Restored Voltage Using Fuzzy Control

![Graph showing THD comparison using Fuzzy Control](image)

THD of the Restored Voltage Using ANN

![Graph showing THD comparison using ANN](image)

Figure 8. THD Comparison outputs: (a) Proportional Integral Derivative Controller (b) Grasshopper Optimization Algorithm (c) Fuzzy Logic Control (d) ANN Controller. From the above comparison outputs ANN based DVR shows the least THD.

Table 1. Results obtained when the four controllers were compared and among the four ann proves the best output for thd

<table>
<thead>
<tr>
<th>Controller</th>
<th>3-phase voltage sag restoration</th>
<th>3-phase voltage swell restoration</th>
<th>% THD</th>
<th>Restoration of voltage and ability to mitigate THD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
<td>89.6%</td>
<td>87.3%</td>
<td>18.90%</td>
<td>Acceptable</td>
</tr>
<tr>
<td>FUZZY</td>
<td>94.2%</td>
<td>92.2%</td>
<td>14.23%</td>
<td>Moderate</td>
</tr>
<tr>
<td>GOA</td>
<td>96.4%</td>
<td>95.6%</td>
<td>8.54%</td>
<td>Better</td>
</tr>
<tr>
<td>ANN controller</td>
<td>97.3%</td>
<td>97.1%</td>
<td>3.27%</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
7 Conclusion

This proposed methodology is to avoid the power quality factors such as voltage sag and swell DVR with photovoltaic system as a backup source using ANN Controller to track the maximum power. Hybrid system with wind and diesel is used as the main source. If the output power supplied from the wind gets disconnected due to fault occurrence or overload conditions then automatically diesel will start to continue the power to the load. In between the transmission and distribution for a certain interval power quality factors such as voltage sag or swell can occur. In order to rectify those problem DVR operated with ANN Controller is used and it proves that it is highly efficient when compared to the other existing systems. All the modules used in this proposed method are clearly described in this paper. The performance of the DVR due to sag and swell have been simulated and the results were shown. Comparative analysis for the proposed system with the fuzzy, PID and GOA, ANN controller has been simulated and the ANN controller proves the best choice among the other controllers. Therefore in this proposed method improvement of power quality, reduction in cost, increase in efficiency are the advantages since renewable energy sources and DVR were used.

References

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Biographies

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