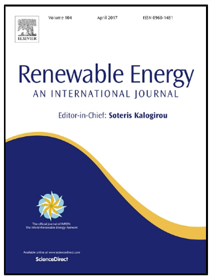

Power quality improvement using STS and DVR in wind energy system

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PII: S0960-1481(17)30013-7

DOI: 10.1016/j.renene.2017.01.013

Reference: RENE 8451

To appear in: *Renewable Energy*

Received Date: 26 October 2016

Revised Date: 14 December 2016

Accepted Date: 06 January 2017

Dear Editor;

The main differences and important of contributions of this paper can be summarized as follows:

- The purpose of this study is the utilization of the wind energy in a safer and more quality way.
- Two systems are suggested for increasing the quality of the wind energy.
- In the first system, the wind energy and the network are connected in parallel with the help of STS
- In the second system, DVR is connected to wind energy system.
- WTS has been made safer and reliable to increase the use of wind turbines for generating electrical power.
- This study will set up a vision for a lot of future studies that will be concerning to raise the quality in wind energy.

Best regards,

Sener AGALAR

Yusuf Alper KAPLAN

Power quality improvement using STS and DVR in wind energy system

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ABSTRACT

Recently, renewable energy has attracted special interest because it seems to be a positive alternative to fossil fuels. European countries, in particular, and many other developed countries in the world have been in search of utilizing wind energy in order to meet the need for energy. The purpose of this study is the utilization of the wind energy in a safer and more quality way. Two systems were suggested for increasing the quality of the wind energy. In the first system, the wind energy and the grid were connected in parallel with the help of static transfer switch (STS), and if the wind energy is cut, the load will be supported by the alternative feeder. In the second system, dynamic voltage restorer (DVR) was connected to wind energy system (WES). The intention is, with the help of DVR system, preventing the fluctuations that might happen in the energy that is produced, due to the variations of wind speed. Both system circuits that are suggested have been created in PSCAD/EMTDC program and the reactions of the circuits in the situation of an error was analyzed in detail. The operation principles of STS and DVR have been explained in detail and then the simulation results have been comprehensively investigated with PSCAD/EMTDC program. The aim of the developed systems is to maintain the power continuity and improve the power quality. Different fault types were applied to the proposed systems and the system responses for these disturbances were examined.

Keywords: Renewable Energy, Wind Energy, STS, DVR, Power Quality

1. Introduction

Energy is the most important resource and strategical tool influencing the shape of society/nations for all countries. The availability and cost of energy significantly affects our quality of life, the structure of national economies, the relationships between nations, and the stability of our environment. The energy consumption increases rapidly due to the growth on population, concerns of countries regarding economical advancements and developments of the technology [1, 2]. The price of conventional energy reserves is rising day by day. Since the traditional energy resources are limited by nature, it is inevitable that all the countries in the world have been affected from this situation economically, politically and environmentally.

The renewable energy sources are inexpensive and infinite in all countries of the world. The increasing problems associated with environment pollution, the importance of renewable energy has increased [3]. Every system in the universe needs energy in order to maintain its existence and the need of energy has been increasing continuously with the growth of population. Especially the technological innovation at power electronic converters boosted the use of renewable energy systems more efficiently. Wind is one of the most popular renewable sources. Technological developments and incremental rate of energy demand have strengthened the attention of wind energy all over the world. Wind power will be 12% of the World's electricity generation according to the EWEA report [4]. The wind turbine based conversion systems have expanded seriously in electrical power generation. As a result of concerning the power quality of the electric systems; sensitivity of consumers has increased due to the expanding curiosity. The system has extended the needs for addressing grid integration concerns and all of electrical disturbances can cause monetary collapse owing to process down-time, operational losses, unemployed manpower and some other serious circumstances. Due to an increasing demand, power conditioning devices need to give a fast response in the existence of grid disturbances with a minimum duration experienced by the load. In the literature, numerous power electronics devices have been proposed and applied in such cases where mitigation of voltage sags are required. Power quality (PQ) problem can be interpreted by the voltage or current deviations from the pure sinusoidal wave. Recently, the usage of power electronic devices and nonlinear loads has increased and this situation will promote different PQ problems. Consequently, PQ of electrical equipment and networks needed to be monitored, controlled, and improved [5, 6].

In this study, classical power system stability of the wind turbine system (WTS) is stated and challenges in the power system involving the wind energy sources are revealed [7]. The output power of wind turbines fluctuates due to variations of wind speed. These power fluctuations cause frequency deviations, power outage and other power quality problem. In this paper, a wind turbine system (WTS) was connected to the

STS and DVR, respectively. These proposed systems were designed by using PSCAD/EMTDC program which contains powerful tools for the wind turbine simulation. The STS and the DVR can become one of the most effective solutions for improving the power quality of WTS. If an alternate feeder connected to WTS, the STS can transfer quickly enough the voltage supply to an alternate source. This paper investigates the use of STS to improve the power quality and STS supports the system during big wind variations and interruptions. Besides, the DVR can also be an impressive solution for various PQ problems. Using DVR with wind turbine can be thought as development for PQ enhancement. DVR can contribute the fastest and mostly cost effective solution to mitigate voltage disturbances by establishing the suitable voltage quality level which is desired by customer. After the fault occurring in grid, voltage sag may scattered through the loads. If DVR is being fixed behind a sensitive load, the voltage level can be restored to its nominal value without a time delay and a power interruption. The combination of WTS and DVR concept is relatively a novel stuff and is still being investigated. It is considered that this will be an efficient solution for numerous power quality issues because of its voltage and current compensating capability.

Power systems generate power for different user applications, and sensitivity to voltage disturbances changes widely for different loading conditions. For customer who uses sensitive loads, even voltage disturbances of short duration can cause serious problems in the manufacturing process. STS and DVR can be applied dually for power quality increment degree and maintain loading condition in the WTS. Recently, a lot of studies related with the operation of wind turbine systems and the power quality of wind energy have been made in many countries worldwide. B. Jain et al. [8] reviewed the main power quality disturbances related with the integration of wind energy system and the control strategies of conversion system. Rona and Guler [9] investigated the integration of the wind turbine systems with the national grids. In this study, a wind power plant which was installed in Trakya region was investigated in MATLAB software. Sinha et al. [10] evaluated the development and simulation of PI controller based pitch angle controlled double fed induction generator system for wind turbines. Verma et al. [11] investigated the influence of the wind turbines in the grid system such as the reactive power, active power, harmonics and voltage variations. L. Ye et al. [12] proposed a short-term wind power prediction model based on physical approach and spatial correlation to characterize the uncertainty and dependence structure of wind turbines'outputs in the wind farm. N. S. Hasan et al. [13] proposed a parallel connection of the Compressed Air Energy Storage (CAES) with a wind turbine to provide a continuous supply to the grid system with reduced wind power input fluctuations. They used MATLAB Simulink to study the effectiveness of the parallel CAES system with changes in wind speed. M. Boutoubat et al. [14] investigated the control of WTS is to improve the reactive power compensation and active filtering capability of a Wind Energy Conversion System (WECS). The proposed algorithm was applied to a Doubly Fed Induction Generator (DFIG) with a stator directly connected to the grid and a rotor connected to the grid through a back-to-back AC-DC-AC PWM converter. A. Ajami et al. [15] investigated the incorporation of two PMSG-based wind turbines to the grid by multi input SSC and a six-switch inverter. The utilized control method promises sinusoidal waveforms and obtains unity power factor in generators side. They used MATLAB Simulink program as an aid to test the converter and the control scheme.

There are different studies in the literature to improve the power quality of the wind energy systems. The distinctive feature of this study is that no such comprehensive studies have ever been carried out for the increasing the power quality of wind energy systems. In proposed new systems, it is aimed to increase the safety and the quality of wind energy with using STS and DVR. In the proposed systems, it is clearly seen that the energy quality can be maintained at any power interruption or temporary electrical disturbances.

In this study, mainly increasing demands for power quality and fail-safe operation of WTS were generally evaluated. Simulation studies of the proposed systems were presented. Two different systems were used to protect the power quality of the load. In Section 2, the wind turbines were briefly explained and the total installed wind energy capacity of the world was given. The all component of wind turbine used in PSCAD/EMTDC program were given. In Section 3, power quality terms, types of the power quality problems, overview of sources of the power quality problems and negative impacts of the power quality problems were described. In Section 4, the characteristics of STS and principle of operation were explained in detail. An analytical model of STS was modeled and its performance was simulated for interruption of wind energy scenarios using the PSCAD/EMTDC program. The performance of static transfer switch for feeder reconfiguration has been assessed and evaluated. In Section 5, the characteristics of DVR and principle of operation were explained in detail. The proposed system which is the combination of the DVR and wind turbine was completely modeled in PSCAD/EMTDC program and simulation results of this system were performed under simulating program to show the performance of the designed system. In Section 6, finally the simulation results were generally evaluated and the advantages of the proposed systems were emphasized.

2. Wind Energy

Recently, due to the reduction of available energy resources and the continuous increase in energy demand; many countries in the world, especially EU countries, are increasing their trend towards using renewable energy resources in energy production [16, 17]. Wind energy source is currently, one of the most cost-competitive renewable energy technologies all over the world when its technical, geographical and social issues are considered. It offers a virtually unlimited, clean and emissions free energy supply [13]. Hence, using wind as a source of power is essential in energy production. Many developed countries constitute long-term plans and forming plan related policies which exploit wind energy potential more efficiently.

The worldwide installed wind power capacity between 2004 and 2015 was shown in Fig. 1. The total installed wind power capacity of the world was 282.842 GW with more than 20% growth rate in the annual market at the end of 2012. The wind power capacity in 2013 reached to 318.463 GW level with an increase of about 35 GW [15]. A new wind power station of about 51 GW was installed in 2014, thereby the total installed power reached to 369.705 GW. Finally, the cumulative installed wind power in the world reached 432.88 GW as of at the end of 2015 [12, 18].

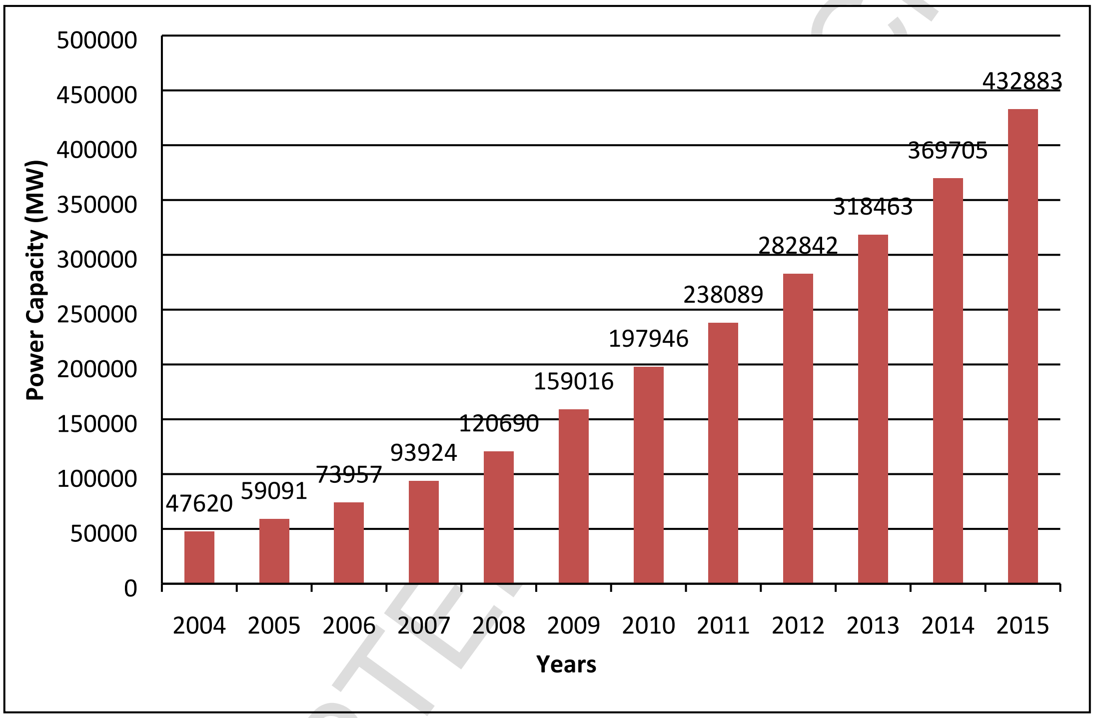

Figure 1. *Installed Wind Power Capacity in the World*

2.1. Wind Turbine Features

Wind power can be efficiently captivated by adjustable speed controlling strategies at turbine. Recently, for the power generation from the wind, synchronous generator with the inverter system is almost adopted. Power factor and adjustable speed controlling can be executed in the wind power generation [19].

The potential of the kinetic energy of the air through the wind turbine blades is given by Eq.1 [14];

$$E_{wind} = \frac{1}{2}\rho V {v_W}^2 \tag{1}$$

In which, ρ is the density of air (kg.m^{-3}), V is volume of air , A_R is the swept area of blade, $v_w$is the velocity of wind (m.s^{-1}) and Where, R_t is the radius of the blade. [20].

$$P_{wind} = \frac{1}{2}\rho A_R {v_W}^3 = \frac{1}{2}\rho\pi R_t^2 {v_W}^2 \tag{2}$$

Extracting all the kinetic energy potential from the wind is unacceptable. The tackled power by the wind turbine in percentage is shown by performance coefficient, Cp.

$$P_{mec} = Cp(\lambda,\beta)\,.\,P_{wind} \tag{3}$$

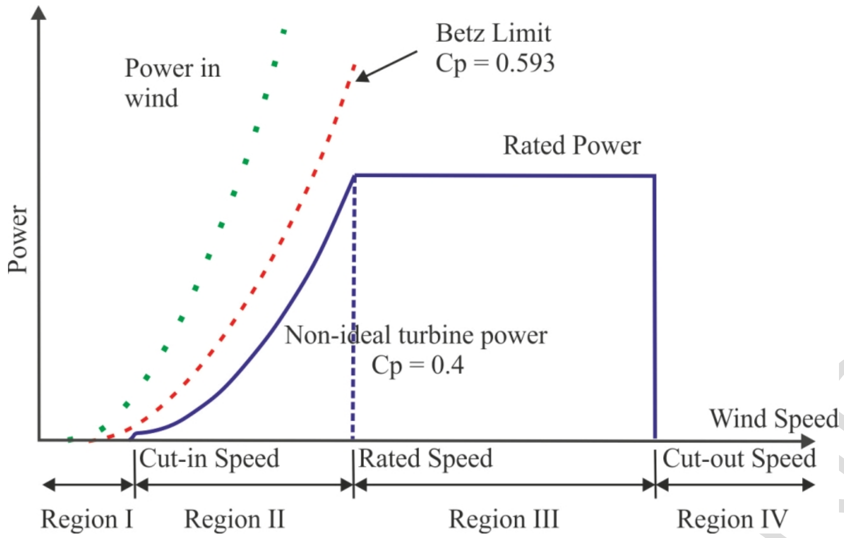

***Figure 2:** Wind Turbine Features*

Coefficient of power equation can be managed from empirical equations derived from experimental setups. The operational regions of the wind turbines were shown in Fig. 2 [21, 22].

2.2 Wind Turbine Components in PSCAD/EMTDC

The PSCAD/EMTDC program is based on time domain simulation which can be used for designing multiphase power distribution systems and grid control units. This program is used for analyzing the study of transient conditions in power systems. It has library of advanced components of power electronics and due to the properties program allows a user to exactly model interactions between grid and loads in different configurations. The PSCAD/EMTDC program has convenient and effective graphical interface and many control tools for designing and analyzing the any power system. The used WTS model for proposed systems in PSCAD/EMTDC program was given in Fig. 3.

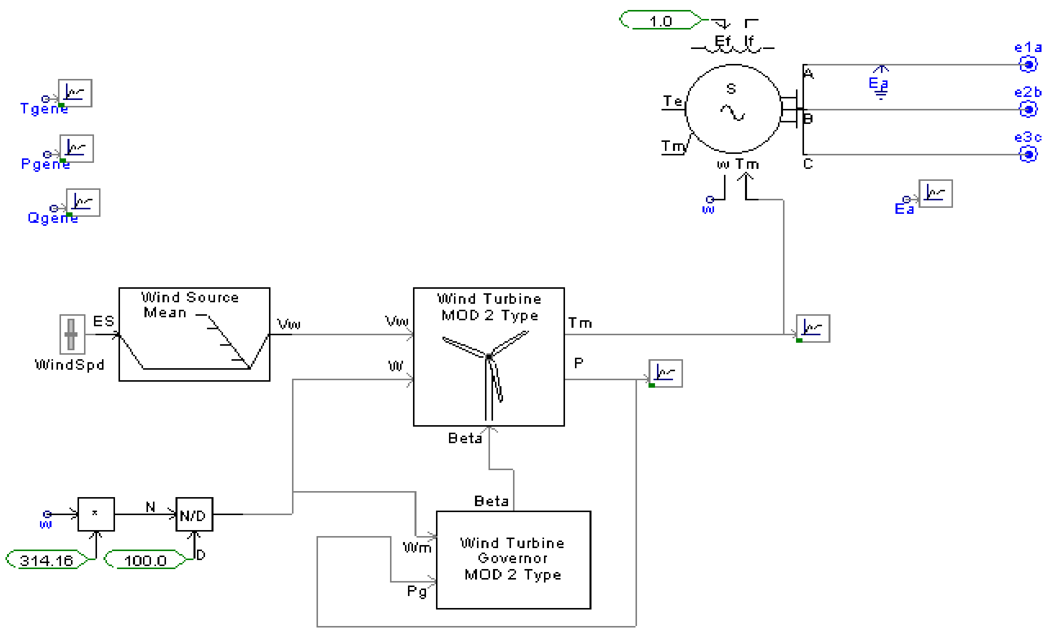

***Figure 3:** Designed WTS in PSCAD/EMTDC*

3. Power Quality

Definition of systems power quality is having a bus voltage that is similar to a pure sinusoidal waveform of required magnitude. Power quality significance extends in industrial applications due to the growth of number of highly sensitive electronic equipments. Because of that; If the power losses are decreased, the interconnected power grids can be made more proper. Currently, power quality defects in the power applications are enlarging because power quality polluting loads are growing as the time passes [4, 5]. Some of the electrical disturbances were shown in Fig.4.

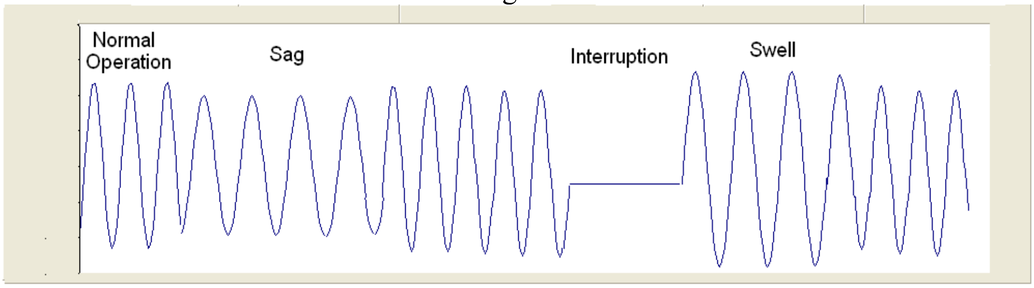

***Figure 4:** Electrical Disturbances*

By increasing wind energy supply sharing and also due to other cases explained below, power systems are becoming less strong. There are many points for PQ of wind turbine systems in power systems. Some of them are given in below [9]:

• Availability of the Grid •Voltage unbalance • Frequency range • Reactive power • Voltage fluctuations • Harmonics• Grid Capacity• Voltage ranges.

Numerous wind energy applications are getting more flexible owing to the advances in power electronics [23]. PQ improvement applications such as compensation of reactive power, STS, DVR, variable-speed generations and energy storage can be used in modern wind turbines [11].

4. Static Transfer Switch

Energy reliability is especially important for critical and sensitive loads. Therefore, any deviation from acceptable levels should be detected very quickly and load should be transferred to an alternative source. Static Transfer Switches are used providing energy to a sensitive load within the highest quality by fast switching between two or more different supplies. The STS contains two or more switching topology that allows an action for changing a load from a WTS feeder to an alternate feeder (AF) [24].

This study deals with the modeling of custom power strategies for WTS in PSCAD/EMTDC. The basic configuration of STS was shown in Fig. 5 [7].

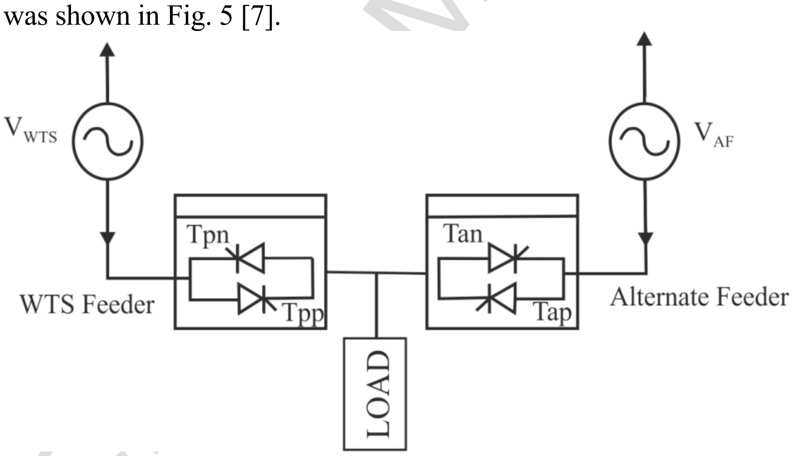

***Figure 5:** Schematic diagram of STS*

4.1 The Operation of STS

Controlling of STS consists of voltage detection logic and a gating power electronics circuit. Based on abc-to-dq0 transformation, line voltages of the system are switched into a synchronously rotating frame. This variable changing can be done by the help of Park's transformation matrix [25]:

$$V_{dq0p} = K_S V_{abcp} \qquad (4)$$

Where

V_{abp} V_{bcp} V_{cap} ; are the line voltages of the WTS,

V_{dp} V_{qp} V_{0p} ; are dq0 components of the WTS voltage in the rotating frame,

K_s is the Park's transformation matrix

The rms value of V_{dp} and V_{qp} can be calculated as:

$$V_P = \sqrt{V_{dp}^2 + V_{qp}^2} \tag{5}$$

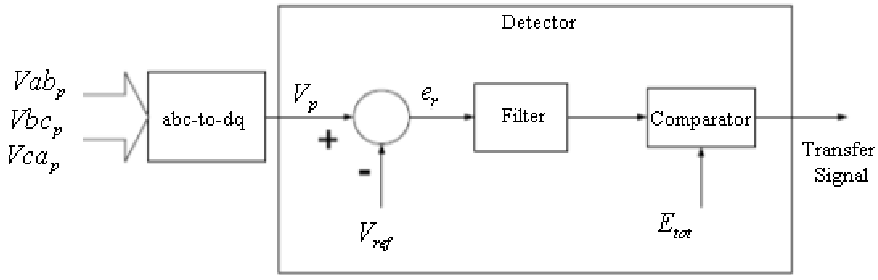

Figure 6. *Block-diagram of the voltage-detection circuit*

The process of abc-to-dq0 transformation block for the proposed system is shown in Fig. 6. The output value of V_P obtained by transformation is compared with the V_{ref} .Then, the error signal can be obtained and this error signal is passed through a low-pass filter, which attenuates impacts of voltage transients. The output of the filter is compared to a tolerance limit E_{tot} which is determined before. Finally, the output of the comparator is the transfer-signal which initiates a transfer process of all system if the wind turbine feeder fails [25].

4.2 The Simulation Model of STS and WTS

The proposed system shown in Fig. 7 is designed in PSCAD program. Primarily, sensitive loads are fed by WTS. In case of voltage sag or interruption, the control circuit of STS transfers the sensitive loads to alternate feeder. The STS is generally applied in uninterruptible power supply devices and in distribution systems for providing connection to alternate sources of ac power for critical loads when WTS break down.

The used parameters of the created system are given as follows:
WTS and alternate source systems:
13.8 kV (Line to line), 50 Hz
$R_{WTS} = R_a = 0.015\ \Omega$, $X_{WTS} = X_a = 0.0101$ H
Transmission line:
8 kV/100kV, 250MVA, 50 Hz Y/Δ step up transformer
100 kV/8kV, 250MVA, 50 Hz Δ/Y step down transformer
Three-phase Δ/Δ load transformer
8 kV/380 V, 1 MVA, 50 Hz
The all used thyristor valves has a snubber circuit composed of R = 1 MΩ and C= 0.001 μF
The series RL load has the following parameters:
$R_L = 0.372\ \Omega$, $X_L = 0.257$ mH
Control circuit parameters of the system are given:
The tolerance limit of Voltage-change of the system: $E_{tot} = 10\%\ V_{ref}$

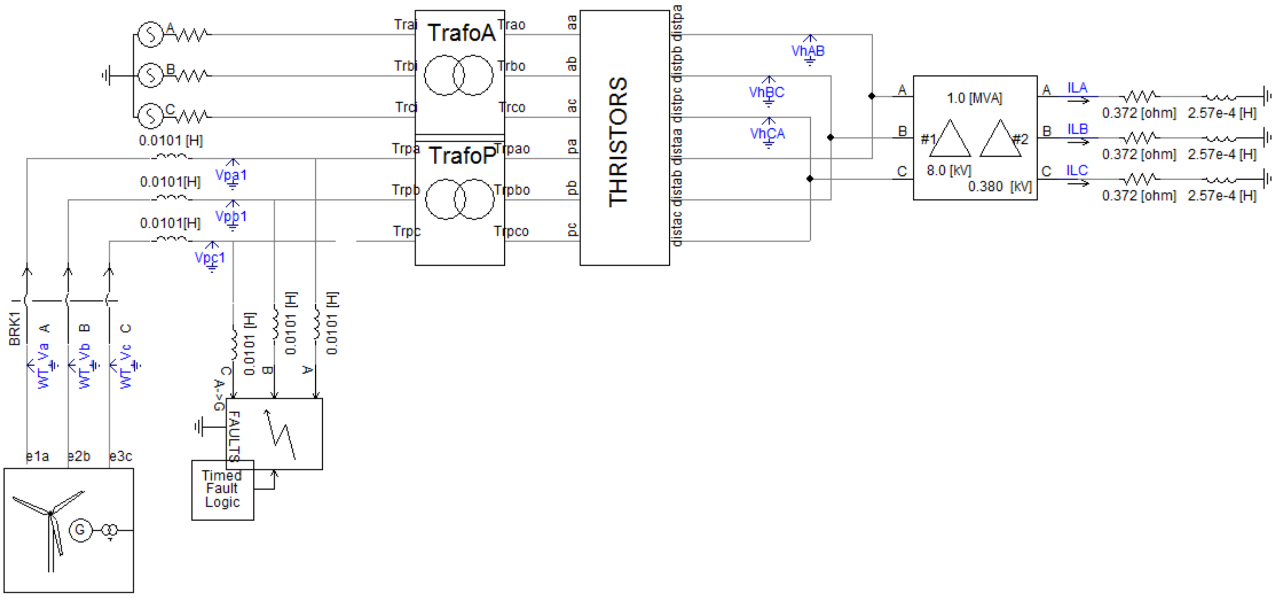

Figure 7: *STS and WTS implemented in PSACD/EMTDC*

4.3 Simulating Results of the system designed with STS and WTS

Recent wind turbines are fitted out with a talent for remaining connected and for supporting the grid continuously during electrical disturbances. Tendency for supplying the grid during deep voltage transients caused by network disturbances related with both the technical features and load of the connected generator. In this study, the goal of making the Wind Power Plant (WPP) performing similar action like CPP is aimed, the response of the proposed system has been observed at during interruption.

Fig. 8 shows the power interruption of the WTS. The fault occurs at t_1= 4.5 s and detected at t_2=4.8 s. The total simulation duration is 0.7 s to show the response of the proposed system.

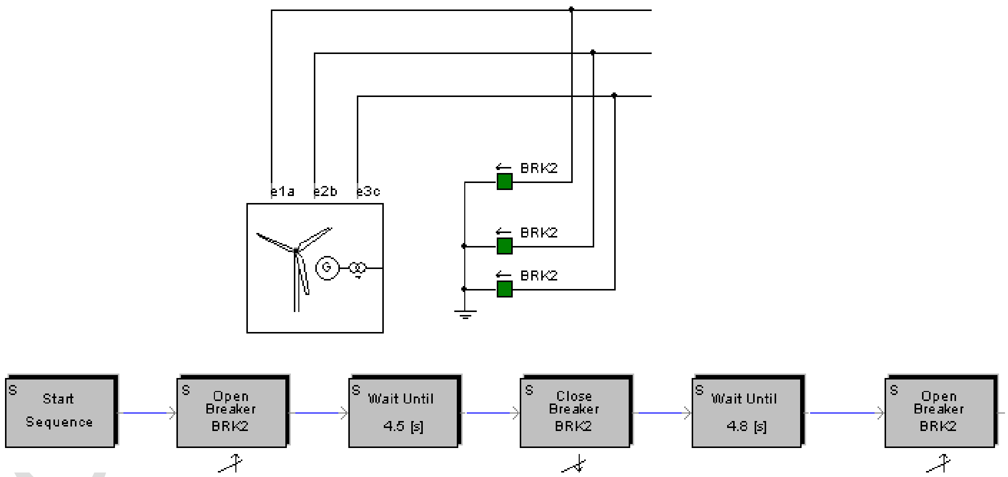

Figure 8. *Interruption circuit of the WTS*

The phase voltages of WTS were shown in Fig. 9 for all duration of the interruption. It is clearly seen that the WTS doesn't supply any energy to the load at during interruption.

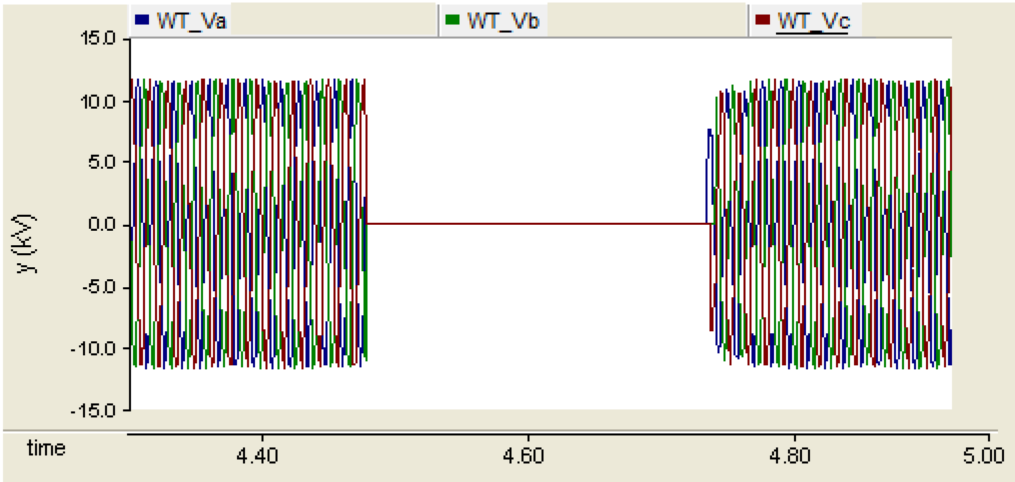

Figure 9. *WTS voltages during interruption*

The currents of WTS measured from the high voltage side of the transformer were shown in Fig. 10.

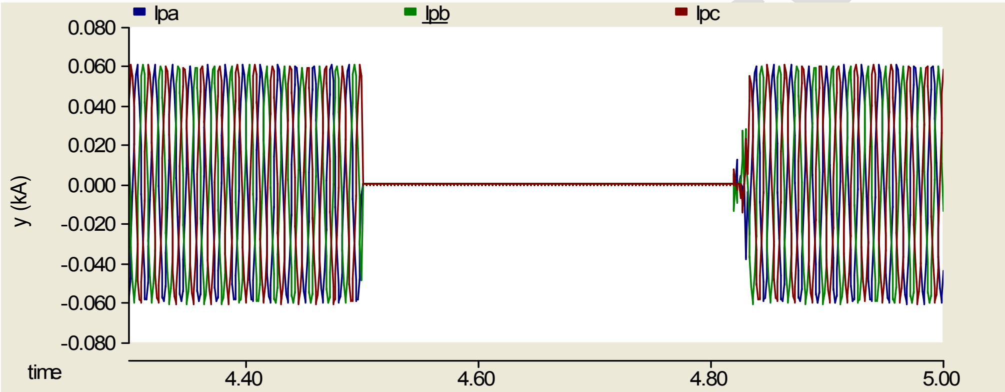

Figure 10. *Line currents of WTS during interruption*

The currents of AF measured from the high voltage side of the transformer were shown in Fig. 11 at interruption duration.

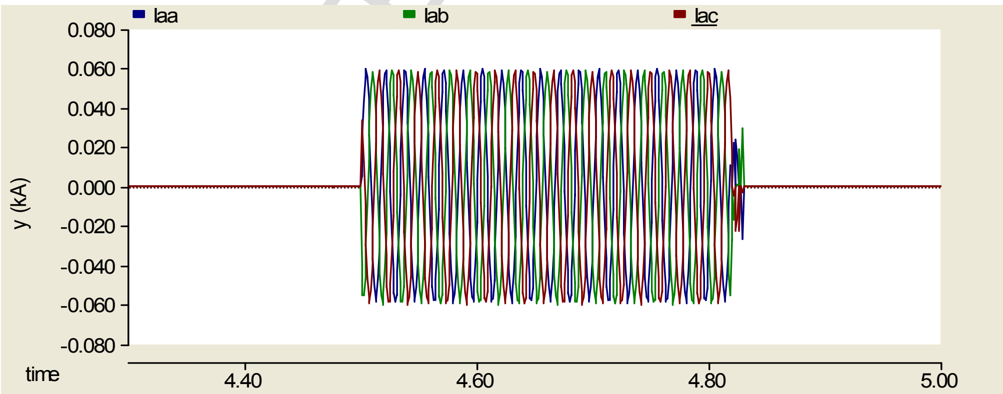

Figure 11. *Line currents of AF during interruption*

Load phase voltages are shown in Fig. 12 at interruption duration.

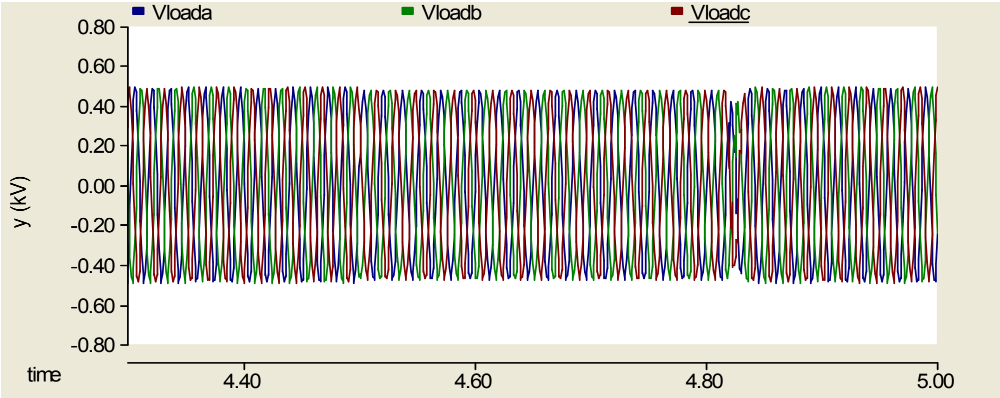

Figure 12. *Load voltages during interruption*

5. Dynamic Voltage Restorer

DVR is a custom power device that uses the power electronics technology and is connected in series between a sensitive load and the source. The basic configuration of DVR is shown in Fig. 13. DVR, a solid state power electronics device, consists of injection transformer which has capacitor bank for energy storing. The capacitor bank as an energy storage device provides DC voltage to regulate the line voltage of load. The primary duty of DVR is to inject a necessary voltage produced by injecting transformer. DVR is one of the Flexible AC Transmission Systems (FACTS) devices which is used to preserve the sensitive loads from disturbances which are voltage sag, voltage swell and voltage harmonics. The DVR which consists of a capacitor bank, a voltage source inverter, injection transformer and filter is connected in series with source [26].

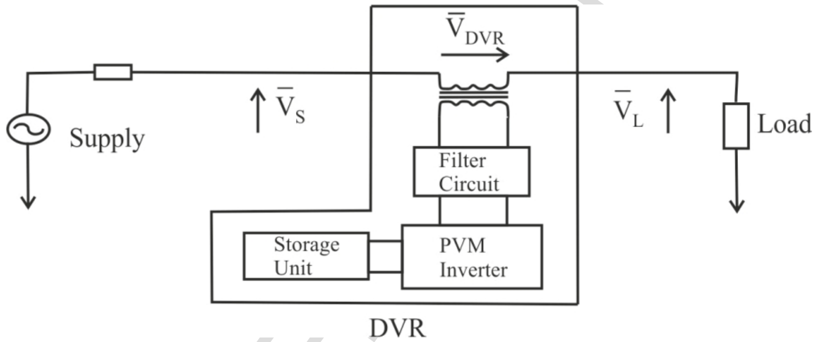

Figure 13. *Schematic diagram of DVR*

5.1 The operation of DVR

In order to mitigate voltage disturbances, DVR injects voltages of suitable magnitude and phase in series with the line as shown in Fig. 14. The DVR injects very small voltage during normal operation condition. But, when a voltage disturbance occurs in grid system the DVR control system calculates the required voltage to protect the sensitive load voltage which is regulated by Sinusoidal Pulse Width Modulation (SPWM) technique with a correct magnitude and phase angle. Then this calculated voltage is injected to the distribution system to maintain the sensitive load voltage. DVR neither absorbs nor delivers real power during standby operation. However, when voltage disturbances occur in the system, DVR delivers/absorbs real power transiently to/from DC link [27].

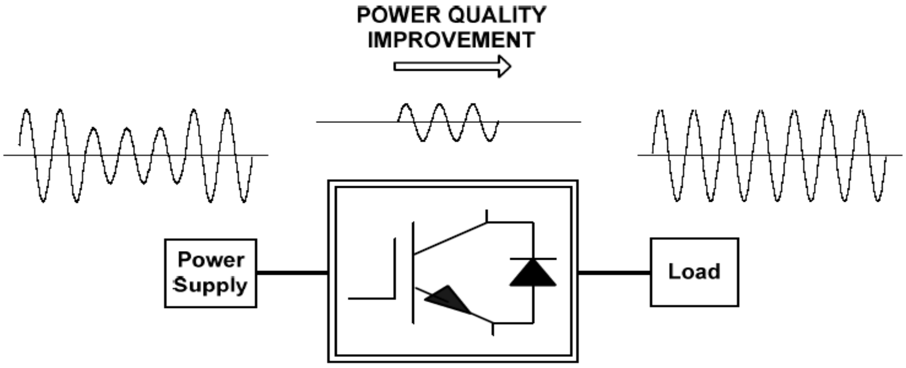

Figure 14. *Operating Logic of DVR*

The all of voltage disturbances are detected, voltage injection strategies are determined and gating signals are produced by the control system of a DVR. The type of sensitive load determines the control strategy to inject compensation voltage.

Some functional requirements are important for the control of a DVR during normal operation and fault operation. DVR is designed to protect the load and to compensate the voltage. Operational cases are given in below.

- The DVR operates in a standby mode and zero voltage injection if there are no errors. But the DVR operates in a self-charging mode if the capacitor bank is to be charged.
- The DVR injects the required voltage to the system in a very short time when a voltage disturbance occurs. This disturbance may be voltage sag or voltage swell which determines the magnitude and phase of injected voltage. All phase of injected voltage are controlled by DVR independently. The DVR supplies the required reactive power to the load with taking active power from the grid [28].

The main purpose of the DVR is to protect the magnitude of the sensitive load voltage V_L at a constant value. There is θ angle between the vector V_L and V_S. So, the issue adding a necessary injection voltage V_C to a given source voltage V_S is how to determine magnitude of the voltage of sensitive load and the proper phase angle θ. The following equation expresses that the required active power for the injection transformer to inject the voltage in series with the line. The impedance of the system ($Z_{th} = R_{th}+jX_{th}$) depends on the fault type of the load bus. When the system voltage (V_{th}) drops, the DVR injects a series voltage V_{DVR} through the inverter of the DVR therefore the desired sensitive load voltage magnitude V_L can be preserved. The series injected voltage of the DVR can be written as

$$V_{DVR} = V_L + Z_{th}I_L - V_{th} \tag{6}$$

Where I_L is the load current

$$P_C = i_L.[V_L\cos(\emptyset) - V_S\cos(\emptyset - \theta)] \tag{7}$$

From Eq. 7, it is clearly seen that the minimum value of P_C occurs at $\phi = \theta$ and the polarity is determined the value of V_S and V_L [29].

If wind turbines are integrated into a distribution network, the dynamics of the system and the power quality of the grid are affected. Wind turbines which can operate variable speed yield more energy than fixed speed operation and these turbines can improve reactive power at the same time it can reduce power fluctuations. Technological improvements of the power electronics provided more economical and useful effects on the variable speed technology. This causes the falling prices and then WTS is mostly connected to grid. The wind turbine cannot be connected easily to the electric power network because control performance of the wind turbine and grid impact of the WTS must be evaluated comprehensively.

5.2 The Simulation Model of DVR and WTS

In this paper, the wind turbine system was designed with DVR. When voltage fault occurs in the system the sensitive load is preserved by using DVR. So, the quality and reliability of voltage can be considerably improved for sensitive and important loads. PSCAD/EMTDC program has been used for modeling and simulating of the proposed system. The proposed method for improving the power quality based wind generator through DVR is applied to the system shown in Figure 6. The DVR can be used very powerfully to protect loads against electrical disturbances. The high-quality power can be supplied to sensitive loads by the

DVR without interruption. Therefore WTS ensures the continuity of electric power to load with sensitive process controls. The all of the following components were described and dimensioned in Fig. 15:

The parameters of the proposed system are as follows:
WTS and alternate source systems:
    13.8 kV (Line to line), 50 Hz
    $R_{WTS} = Ra = 1$
Three-phase Y/Δ load transformer
    7.5 kV/2 kV, 1 MVA, 50 Hz
The all used thyristor valves has a snubber circuit composed of R = 1 MΩ and C= 0.001 μF
Filter circuit paremeters are:
    R = 10 Ω, L =1.64 mH , C =5.66 μF ,
Load system's parameters:
    R = 56.25 Ω, L = 0.13 H

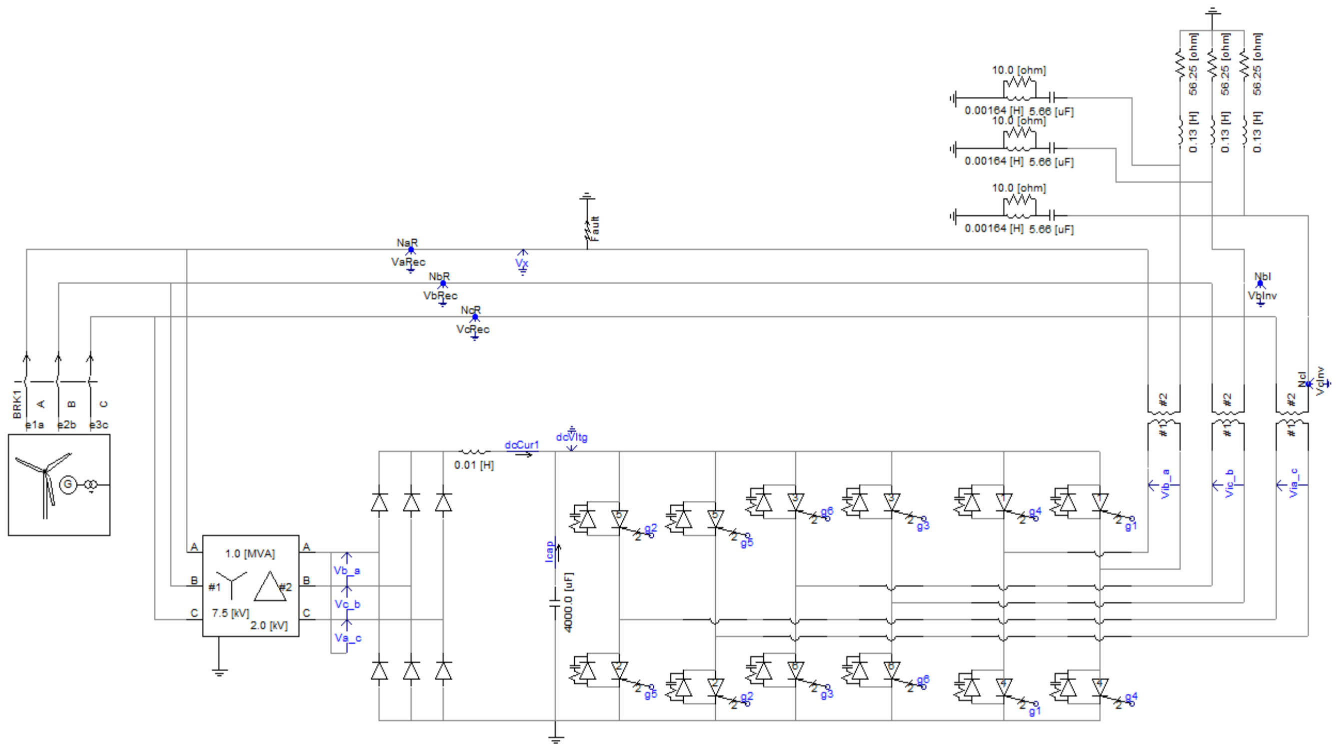

Figure 15. *DVR and WTS implemented in PSCAD/EMTDC*

The main aim of this proposed system is to provide simulation and dynamic performance WTS and DVR impact analysis capability of system based on. The characteristic of DVR was shown in PSCAD/EMTDC simulating program which is used to analyze the response of the system. Fig. 15 shows simulation model of WTS which is series connected to DVR and sensitive load.

5.3 Simulating Results of the system designed with DVR and WTS

The PSCAD/EMTDC program is used to analyze the operational characteristics of DVR and WTS. In this simulation DVR supplies fixed voltage and current by injecting power to the WTS and naturally the power of wind turbine become steady also. Fault occurs in the network between t = 1.2 and t = 1.4 time durations. Fig. 16 shows the WTS source voltage for all phases at fault duration. The total simulation duration of the system is 0.2 s.

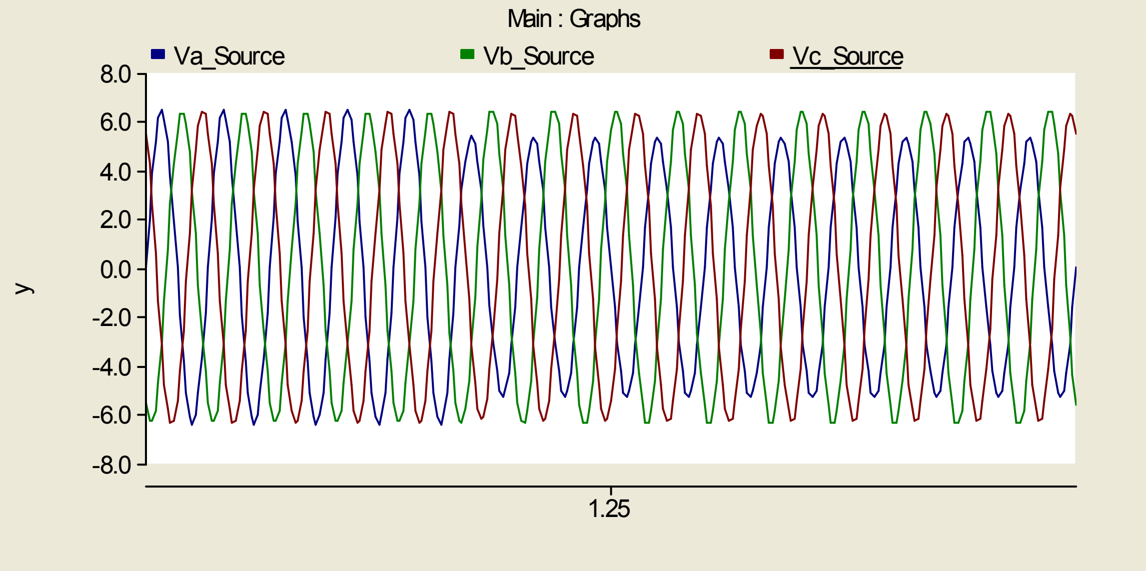

Figure 16. *Phase voltages of WTS*

The wind turbine voltage for phase A was shown at fault duration in Fig. 17. The voltage drops about 20% of the rated voltage at fault duration.

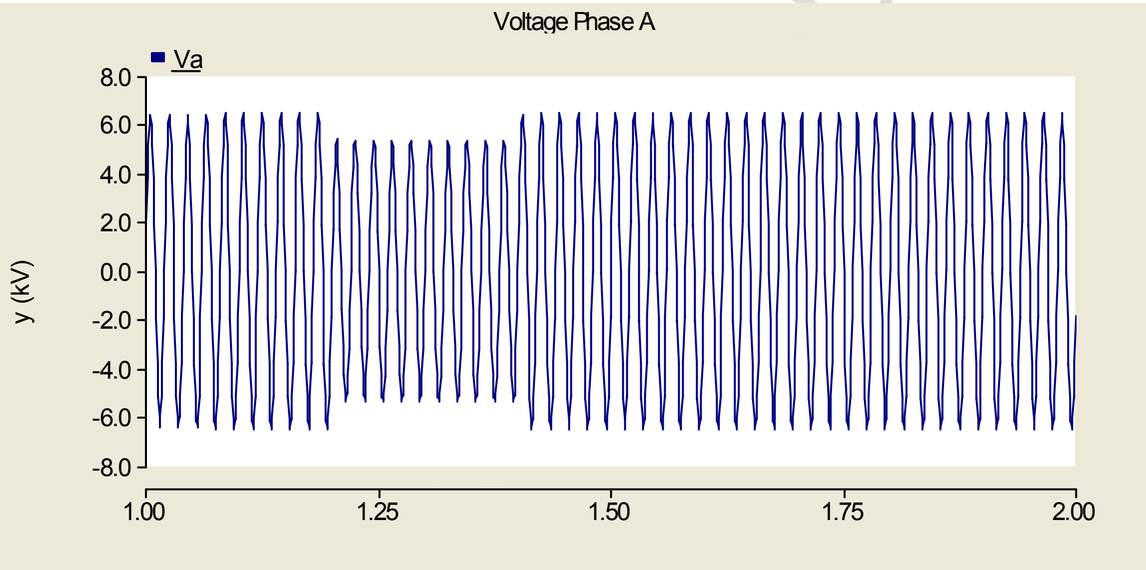

Figure 17. *Phase voltage of the WTS*

The compensation methods of a DVR depend on different types of voltage disturbances, power ratings of DVR and the various conditions of the sensitive loads which can be sensitive phase angel jump or magnitude change. Fig. 18 shows that the DVR injected voltage to the system at fault time.

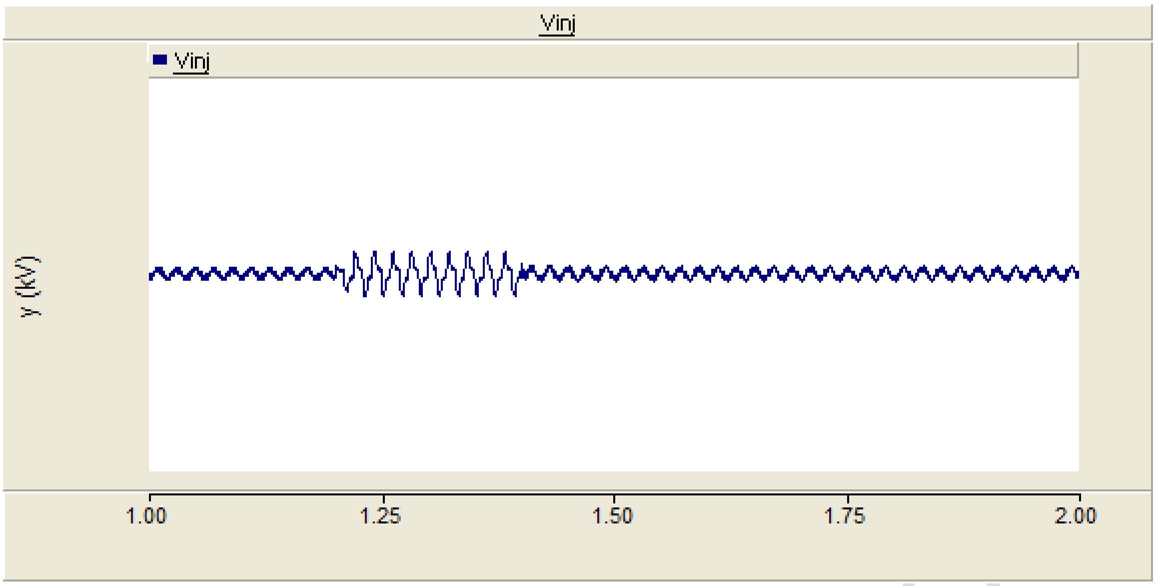

Figure 18. *Injected voltage by the DVR*

The simulation results show the operation characteristics and the performance of the DVR with voltage sag and it is clearly seen in Fig. 19 that DVR can constantly compensate the voltage sag for the sensitive load.

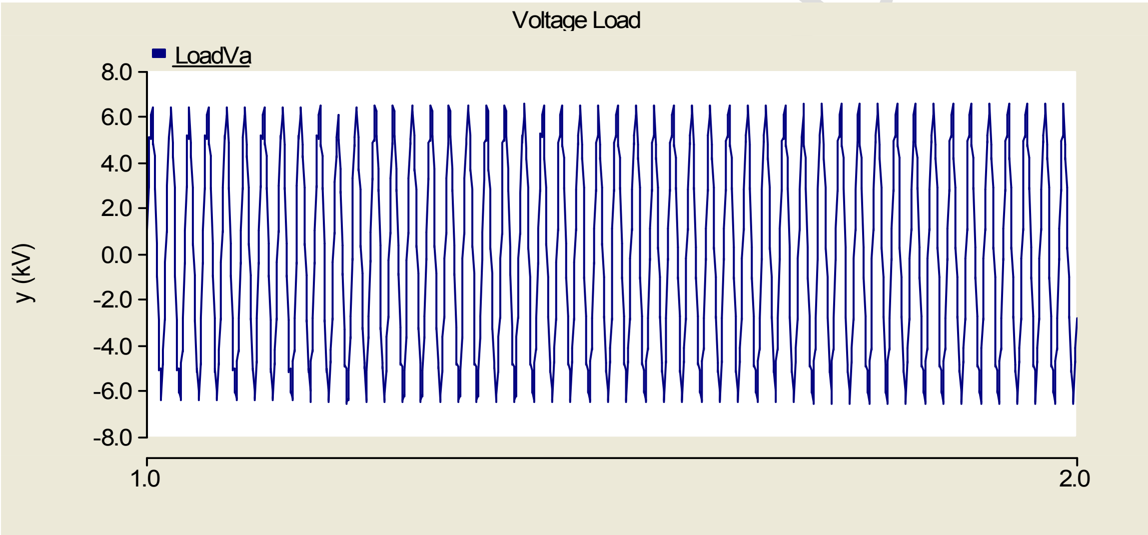

Figure 19. *Phase voltage of the Load*

6. Conclusions

As a result of technological improvements and increasing population the power distribution network of utilities is expanding rapidly and the share of wind energy in electrical power system is getting higher each year. In these circumstances, it is necessary that utilities must provide sustainable, reliable and good quality power. DVR and STS used in proposed systems can compensate voltage interruption, voltage sag and swell. In this paper, installed capacity of the wind energy power was given at the worldwide. Moreover the operational principle of STS and DVR were generally justified and the current status of WTS was summarized, respectively. It is clearly seen that faults have no effect on the load current and voltage at the fault time. The responses of the proposed systems during fault period were investigated and control solutions were developed within this study. According to the results obtained, the reliability and the quality of wind energy have been increased in both systems. The sudden accelerations and decelerations in the speed of the wind have been a huge problem for the reliability and the quality of the wind energy. With the help of these and similar systems, the confidence in the wind energy and the utilization of the wind energy will escalate. This study will set up a vision for a lot of future studies that will be concerning to raise the quality in wind energy.

References

[1] Gürü M. and Keskïn A., "Evaluation of Biodiesel Production, Engine Performance, and Emissions." Journal of Electronic Materials. 45 (8), pp: 3882-3888, 2016

[2] Firat, S., "Application of Efficient & Renewable Energy Technologies in Low Cost Buildings and Construction", Journal of Polytechnics, 17(1), pp: 1-2, 2014

[3] Bayindir R., Yesilbudak M. , Cetinkaya U., "Modelling and Analysing of Electricity Transmission Infrastructure of Ankara, Turkey: A Case Study on the Critical Line Scenarios." Gazi University Journal of Science, 28(4), pp: 587-597, 2015

[4] Wu Z., Rui-fa C., "Improved Low Voltage Ride-through of Wind Farm Using STATCOM and Pitch Control", Power Electronics and Motion Control Conference, IPEMC '09, China, 2217 – 2221, 2009

[5] Sharanya M., Basavaraja B., Sasikala M., "An Overview of Dynamic Voltage Restorer for Voltage Profile Improvement", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Vol: 2, 26-29, 2012

[6] S. Jashfar, S. Esmaeili,M. Zareian-Jahromi,M. Rahmanian, "Classification of power quality disturbances using S-transform and TT-transform based on the articial neural network", Turk J Elec Eng & Comp Sci , Vol: 21, 1528-1538, 2013

[7] Meral E.M.,Teke A., Tumay M., Overview of an Extended Custom Power Park, 2nd IEEE International Conference on Power and Energy (PECon 08), December 1-3, 2008, Johor Baharu, Malaysia

[8] Jain, B., Jain, S., & Nema, R. K. , "Control strategies of grid interfaced wind energy conversion system: an overview.", Renewable and Sustainable Energy Reviews, 47, pp:983-996, 2015.

[9] Rona, B., & Güler, Ö., "Power system integration of wind farms and analysis of grid code requirements.", Renewable and Sustainable Energy Reviews, 49,pp: 100-107, 2015.

[10] Sinha, A. K., Diwan, R., & Sharma, D., "Development and simulation of pi controller based pitch angle controlled dfig system for wind turbines.", Int. J. Adv. Engg. Res. Studies/IV/II/Jan.-March, 326-330, 2015.

[11] Verma, A. R., Kamani, P. L., & Kapadia, R. R., "A review on grid power quality improvement in wind energy system using STATCOM with BESS.", In Journal of Emerging Technologies and Innovative Research , 2 (1), 2015

[12] Ye, L., Zhao, Y., Zeng, C., & Zhang, C. , "Short-term wind power prediction based on spatial model.", Renewable Energy, 101, pp: 1067-1074, 2017.

[13] Hasan, N. S., Hassan, M. Y., Abdullah, H., Rahman, H. A., Omar, W. Z. W., & Rosmin, N., "Improving power grid performance using parallel connected Compressed Air Energy Storage and wind turbine system.", Renewable Energy, 96, pp: 498-508, 2016.

[14] Boutoubat, M., Mokrani, L., & Machmoum, M., "Control of a wind energy conversion system equipped by a DFIG for active power generation and power quality improvement.", Renewable Energy, 50, pp: 378-386, 2013.

[15] Ajami, A., Alizadeh, R., & Elmi, M., "Design and control of a grid tied 6-switch converter for two independent low power wind energy resources based on PMSGs with MPPT capability.", Renewable Energy, 87, pp: 532-543, 2016.

[16] Bilir, L., İmir, M., Devrim, Y., & Albostan, A., " Seasonal and yearly wind speed distribution and wind power density analysis based on Weibull distribution function.", International Journal of Hydrogen Energy, 40(44), pp: 15301-15310, 2015.

[17] Qi, W., Liu, J., & Christofides, P. D , "A distributed control framework for smart grid development: Energy/water system optimal operation and electric grid integration.", Journal of Process Control, 21(10), pp: 1504-1516., 2015

[18] GWEC(GlobalWindEnergyCouncil), Global wınd 2015 report, April, 2016.

[19] Kai T., Tanaka A., "A New Smooth Scheme for Power Fluctuation using Inverter of Wind Power Generation with Doubly Fed Induction Generator, Electrical Machines and Systems.", ICEMS 2008, Wuhan, China, pp:2390 – 2395, 2008

[20] Cetinay, H., Kuipers, F. A., & Guven, A. N., "Optimal siting and sizing of wind farms.", Renewable Energy, 101, pp:51-58, 2017

[21] Hguyen T.H., Lee D.C., "Improved LVRT Capability and Power Smoothening of DFIG Wind Turbine Systems", Journal of Power Electronics, 11(4), pp: 568-575,2011

[22] Bhandare, A.M., Jadhav, K., Ghat, M.B.: 'Performance of power coefficent & power with respect to variable wind Speed' , IEEE Energy Efficient Technologies for Sustainability (ICEETS), Nagercoil, pp. 466-471, 2013

[23] Yang, W., & Tian, S. W., "Research on a power quality monitoring technique for individual wind turbines.", Renewable Energy, 75, pp:187-198, 2015
[24] Rauch, G.B., Shew, F., Horner, J.: 'Application of Power Quality Recording Instruments for monitoring Medium Voltage Static Transfer Switch Operation', IEEE Power Engineering Society Summer Meeting, 1, pp: 420- 425, 1999
[25] Sannino, A., "Static transfer switch: analysis of switching conditions and actual transfer time", Power Engineering Society Winter Meeting, Colombus, 1, pp: 120 – 125, 2001
[26] El-Gammal M. A., Abou-Ghazala A. Y., and El-Shennawy T. I., "Dynamic Voltage Restorer (DVR) for Voltage Sag Mitigation", International Journal on Electrical Engineering and Informatics, 3, pp:1-11, 2011
[27] H. Swapnali , S. Swagata, B. Rahul ,D. Smriti, "Application of Dynamic Voltage Restorer in Electrical Distribution System for Voltage Sag Compensation", The International Journal Of Engineering And Science (IJES), 2,pp: 30-38, 2013
[28] Murali D., Rajaram M., "Simulation and implementation of DVR for voltage sag compensation.", IJOCA , 23, 2011
[29] M.H. Haque "Compensation of Distribution System Voltage Sag by DVR and D-STATCOM", In proceeding of: Power Tech Proceedings, IEEE Porto, 1, 2001