INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE

ISSN: 2057-5688

NEW CONTROL TECHNIQUES FOR IMPROVED POWER QUALITY RELIABILITY

Keelagaram Gunaprasad, Research Scholar, Department of Electrical Engineering, Monad University, Hapur, U.P
Dr. Mandadi Surenderreddy, Associate Professor , Supervisor, Department of Electrical Engineering, Monad University, Hapur, U.P

ABSTRACT:

Transformers provide a variety of tasks for the electrical grid, including voltage conversion and electric isolation. In the Power Quality Conditioners, it performs the functions of both a series and shunt transformer. The transformer is large and costly when used at low frequencies. Due to its massive weight and bulk, the performance and maintenance of the current 50 Hz power transformer are constrained in many applications, including wind energy conversion, electric ships, and power quality conditioners. By swapping out the large transformer for the smaller one, this restriction is removed. Since it is accomplished by raising the operational frequency of the transformer. It is used since it is practical and affordable to change the operating frequency and there is a fair chance the Power Electronic Converter will be designed for high-frequency operation. Because of its versatility, portability, and increased power handling capability, the power electronics-based transformer idea has improved significantly.

1 Introduction

In power systems, power transformers are essential. Power transformers with a big core are used to convert greater transmission voltage levels to lower distribution voltage levels. The huge weight and bulk of the current 50 Hz power transformer is a restriction in many applications, such as wind energy conversion and electric ship. The globe is heading towards the concept of a "Smart Grid," where the size of the equipment is decreased, as a result of the advancement of technology. Power quality difficulties arise as a result of the size decrease. The equipment with smaller dimensions performs better and is more efficient, and since they need a high-quality supply, they are particularly sensitive to problems with power quality. Any power issue that manifests as voltage, current, or frequency aberrations that causes failure or malfunction of client equipment is referred to as a power quality problem (Dugan et al. 2003). Electric and electronic equipment, which rapidly increase non-linear loads, seriously degrade the quality of the power system at the transformer end by interfering with voltage. Voltage sag, voltage swell, frequency deviation, harmonics in current and voltage, flashing, phase shift, and transients are examples of power quality problems. Due to the pollutants (harmonics) caused by more losses in the transformer core, which raises operating costs and generates more heat in the power system, reducing their life expectancy, the waveform's shape changes.

The major goal of this study is to decrease the size of the transformer utilised on both the distribution side and in power quality conditioners. Because huge transformers need a lot of installation space, money, and regular oil changes. They also have problems with maintenance and transportation. The poor voltage control, inrush currents, and spectrum distortion brought on by the nonlinearity of the B-H curve in a bulky transformer also create harmonics. A size-reduced transformer's frequency must be carefully considered while developing it. To minimise the size, the frequency must be raised. The frequency level of powerful electrical equipment may be simply raised from Hz to kHz. The heavy transformers may be replaced by power converters and a high-frequency transformer. An effective controller is employed for the converters' switching function. The Power Electronic Transformer (PET) idea is used in this study to reduce the size of the distribution transformer and Power Quality conditioner. It is utilised in the Wind Energy Conversion System (WECS) and in various frequency grids. The PET idea is used in power quality conditioners with three stages and one stage, and its effectiveness in distribution lines, WECS, and in various frequency grids with the harmonic distortions is evaluated.

Transformers that operate at 50 hertz need regular oil changes and take up a lot of space during installation, shipment, and maintenance. Additionally, a big transformer adds to the power system's harmonics, which are brought on by bad voltage control, inrush currents, and spectrum distortion brought on by the B-H curve's nonlinearity.

Poor voltage regulation occurs as a consequence of the secondary voltage fluctuating as a result of the non-linear load current. Secondary voltage sag has an impact on the network's power quality. Tap changers are used to maintain the voltage within the tolerance stipulated by the national regulations (NRS-048). An electro-mechanical switch known as a tap changer may be observed in the transformer's primary. This electromechanical switch alters the transformer's turns ratio by adding or removing primary windings. To adjust the output voltage, tap changers are now offered in manual and automated variants. Solid-state tap changers that employ instantaneous voltage control are the subject of ongoing research (Fourie et al. 2009). Solid state tap changers are used to reduce the secondary voltage by around 5%.

2 Literature Survey

Congestion in a gearbox system is caused by momentary overloading of the gearbox components, but if it is not adequately managed, it may result in the failure of crucial gearbox routes, which might endanger the security of the system. Due care must be made while executing contracts in a day-ahead market so that authorised contracts do not cause congestion, not even in a crisis situation. In a deregulated electricity market, the system operator is in charge of determining the required steps to make sure that no network restrictions are violated. Over the last three decades, several projects involving the deregulated electrical system's congestion management have been undertaken. The many solutions for managing congestion that have been put out in the literature are reviewed in this chapter.

In order to run the electric network safely, the transmission network is often subject to a number of constraints, including stability limits, voltage limits, and heat limits, most of which are relevant at any one moment. The electrical utilities were pushed to boost their production as a result of the rising global demand for electricity. After deregulation, the main goal of the electrical utilities is to run this expansive electric power network safely and profitably. In order to satisfy demand economically, the least price generator is given preference. The likelihood of exceeding the limitations rises together with the growth in the amount of power flowing through the gearbox lines that enable efficient functioning. If this limit is reached, the system is considered to be overcrowded [1]. To keep the network secure, the power system must operate within certain parameters; when these parameters are exceeded, there are significant blackouts that have serious social and economic repercussions. The most essential issue is therefore regulating the transmission network for congestion management [2]. Rescheduling, load reduction, and active and reactive power assistance are the typical strategies used by system operators to mitigate congestion. As each participant seeks to maximise his or her profit, the market operator in a deregulated system utilises the resources at close to their rated capacity [3]. Rescheduling is hence the system operator's more general strategy in a deregulated environment [1]– [4], with load curtailment being the operator's last recourse. With random fluctuation in power transaction, congestion relief becomes a difficult issue. Thus, for the dispatch of electricity in a crowded line to reduce congestion, the best generator choice is required. The most popular congestion management approach for large power networks has been documented in [5]–[10], and it involves using the generator sensitivity index to choose the generator for the best rescheduling to control congestion. To maintain network congestion during rescheduling, the generation is either raised or lowered.

The widespread use of Distributed Generators (DG) for congestion control in recent years is a result of the power system's technical improvement [11–14]. DG is utilised to meet local load as opposed to the conventional central power plant [15]. Fuel cells, wind, photovoltaic (PV), geothermal, biomass, and gas turbines are among the several types of DGs. Congestion control, voltage profile improvement, loss reduction, and system dependability are some of the technical benefits of DG penetration. Benefits of DG are more noticeable in more populated areas [16] and are achievable if DG is installed in the best possible location and size. A network might collapse due to improper installation, causing significant societal and financial harm.

Congestion in the network generates a significant difference in Locational Marginal Price (LMP) in a deregulated environment, and this is a signal to determine the degree of congestion in the network. The LMP pricing technique is commonly used in markets like NYISO, CAISO, etc. The price in LMP is made up of costs for energy, traffic, and network losses. when a result, LMP at each bus changes when losses and congestion increase. Congested areas have higher LMP values than non-congested areas [17]. As it can send electricity in a specific direction at a given moment when the demand exceeds the transmission capacity, DG might have a large influence in such a circumstance and be extremely useful in minimising LMP discrepancy. By strategically positioning and scaling DG, authors in [18] presented a solution for congestion control. In order to determine the ideal size, authors set the DG at the maximum LMP node and reconstructed the OPF while taking the cost function into account. The findings demonstrate that the LMP was somewhat decreased. After that, writers in [12] presented a transmission congestion rent (TCR)-based strategy for the best placement of DG by arguing that the highest LMP strategy would cause congestion on other lines. The size that generates the most social benefit is regarded to be the ideal size for DG, according to the authors' calculation of the optimal size of DG. The findings demonstrate that they significantly reduced the LMP difference. For the best location of DG and FACTS, authors [17]–[19] suggest a TCR-based strategy and discover very encouraging results. All of the writers covered in this article employed various techniques to identify the ideal site, but they paid little consideration to selecting the right DG size. They either set the DG size after weighing all potential sizes or modified the OPF by adding DG cost coefficients.

3 Methodology

Loads are designed for optimal performance at the rated supply voltage in a perfect power system. These consumer loads, however, are not designed to operate at their best across a wide variety of supply voltages. The frequency of ac mains is the same. Therefore, in an ideal situation, the voltage and frequency should be consistent, at the rated value, and free of harmonics at each consumer site, while the power factor should be kept at unity at the ac mains. This naturally leads to the requirement that no consumer's power supply should be interfered with as a consequence of fluctuations in the current consumed by other customers.

The phrase "Quality of Power Supply" may be used to describe how closely the voltage and frequency are to their rated values, how harmonic-free the voltage and current are, and how close the power factor is to unity. Additionally, how reliable an uninterrupted power supply is as well as how flicker-free the voltage is. The degree of phase current and voltage balance in three-phase systems is also taken into account when discussing power quality.

The majority of the loads in our current electrical system either use power electronic converters to connect or absorb reactive power, which introduces harmonics into the electrical system. Single-phase loads also throw the three-phase current and voltage out of balance.

The demand for energy is rising daily as a result of the improvement in peoples' standards of life and the growth in population. Before the current downturn, India's economy had been expanding at a rate that was close to double digits, and it is predicted that this rate would be about 8.5% in 2012–2013. Making sufficient amounts of inexpensive, high-quality electricity accessible is essential for maintaining this economic growth rate. The production of power, on the other hand, has not been able to keep up with the increase in demand. As a consequence, there are ongoing undervoltages during periods of high demand and more blackouts. Blackouts have grown by 124 percent in developed nations like the USA during the last 20 years, from 41 blackouts between 1991 and 1995 to 92 between 2001 and 2005. Total interruption time amounted to 214 minutes annually on average [1]. In contrast to this, the typical utility consumer in a developing nation like India has a much higher number of blackouts and those that last longer each year.

4 Experiments & Results

The PET idea has been used in DVR because it is flexible, lower in size, and has a higher power handling capability. Since the size of the DVR is dependent on the size of the injection transformer in the DVR, it is simpler to implement the power electronics converter based transformer into power quality conditioners like the DVR if the analysis is based on its size and cost. Since power supply trends are moving in the direction of miniaturisation, PET topology has been used for the analysis from Hz to kHz range of frequency in order to minimise the size of the injection transformer.

As a consequence, magnetic component size often decreases as switching frequency increases (Bolborici 1999). As a result, the study is conducted using core material that is appropriate for the injection transformer core. There have been several studies on transformers, although the majority focus on the design of the transformer, loss reduction, loss calculation, or inductance calculation (Jamerson (2002); Hurley & Wolfle (2013); Bahmani (2012); Sippola & Sepponen (2002)). How much size and weight reduction at high-frequency operation may be accomplished, leading to a decrease in transformer cost, is a subject that has as of yet no clear solution. Therefore, a thorough examination is required to determine the usefulness of the suggested gadget.

As a result, this chapter examines a methodical analysis of the high-frequency transformer's size and weight in relation to operating frequency based on the weight of the active component of the transformer, its cost, and its core and winding losses (including eddy current loss) for the 50 Hz, 100 Hz, and 150 kHz DVR injection transformers for various PET topologies. This computation, which will offer workable information for the appropriate topology, is suggested for the installation of power quality conditioners in the power distribution system.

Transformer for Injection: The line is linked in series with the injection transformer. When a sag develops, the transformer injects or adds the necessary voltage to the source voltage. The phase shift and consequent voltage drop are impacted by the DVR mode of operation, which in turn relies on the transformer's specifications.

Transformer Design and Parameters: The magnetic flux and current in the coil start at zero at the beginning of compensation and progressively grow. It indicates that the transformer flux is almost twice as high as the typical flux at its greatest value. The transformer experiences an inrush current as a result, necessitating a transformer with a rating two times that of a DVR. The transformer is thus huge and costly.

Table 4.1 Injection Transformer parameters of DVR

Type	Single Phase, Core-Type Core
Frequency	100 Hz
Rated Power	2 kVA
Primary voltage	Rated 230 V
Secondary voltage	Rated 60 V

Table 4.2 Measured Dimensions for the 50 Hz and 100 Hz DVR Injection Transformer

The plot of the voltage waveform is presented in Fig. 3.1 for only 200 samples, and the Fourier-series equation of the waveform that was simulated in MATLAB is provided below. The voltage waveform's fundamental frequency is 50 Hz, and 1024 sample points of the voltage waveform are collected for analysis.

$$v(t) = 100\sin(\omega t + 30^{o}) + 50\cos(2\omega t + 60^{o}) \\ +25\sin(3\omega t + 120^{o}) + 20\sin(5\omega t + 150^{o}) + \\ 10\sin(7\omega t + 50^{o}) + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

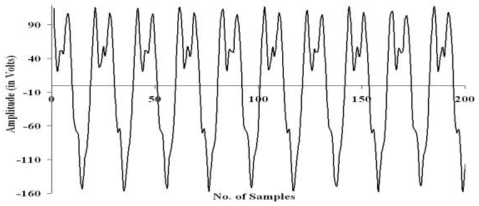
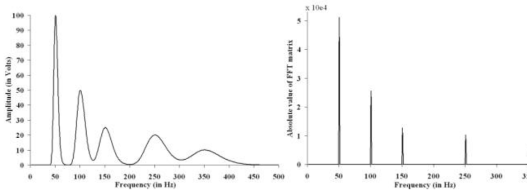


Fig. 4.1 The complex voltage waveform

On the voltage equation time-series, ST and FFT have both been used. The frequency spectra derived from ST and FFT are shown in Fig. 3.2. The basic frequency of 50 Hz and the 100 Hz frequency are both seen to have prominent peaks. At 150 Hz, 250 Hz, and 350 Hz, there are brief peaks. In Table 3.1, the peak amplitudes are listed.

Sharp peaks can be seen in the plot of Fig. 3.2(b) at frequencies of 50 Hz, 100 Hz, 150 Hz, 250 Hz, and 350 Hz. Thus, it is clear from both Figs. 3.2(a) and (b) that the 2nd, 3rd, 5th, and 7th harmonics are the primary frequency components of the voltage waveform, in addition to the fundamental. This result and equation (3.1) are in good agreement. The absolute values of the S-matrix (STA matrix) may be used to determine the harmonic amplitudes. The comparison among the actual values of the harmonic magnitudes (derived from equation 3.1) versus the ones obtained from the STA matrix is shown in Table 3.1.



(a) (b)

Fig. 4.2: (a) Frequency spectrum of waveform in Fig. 3.3 obtained from S-Transform (b) Frequency spectrum of waveform in Fig. 3.1 obtained from FFT

Dimensions	50 Hz	100 Hz
Net iron area, A_i (in m^2)	4.633×10^{-3}	2.316×10^{-3}
Diameter of circumscribing circle, '*d*'	0.076	0.0538
Gross Core Area, A_{gi} (in m^2)	5.148×10^{-3}	2.573×10^{-3}
Width of the stamping, '*a*'	0.07175	0.0507
Distance between core center, *D* (in m)	0.11479	0.08112
Width of the window, W_w (in m)	0.0387	0.0273
Window area, A_w (in m^2)	4.4640×10^{-3}	4.46499×10^{-3}
Height of window, H_w (in m)	129.19×10^{-6}	183.15×10^{-6}
Depth of the yoke, D_y (in m)	0.07175	0.0507
Height of the yoke, H_y (in m)	0.07175	0.0507
Height of the frame *H* (in m)	0.1436	0.10158
Length of the frame *W* (in m)	0.18654	0.13182

5 Conclusion

In this work, CPF analysis and the FVSI index are used to determine the SVC's ideal position. Bus 10 is identified as the weakest bus, and SVC is linked to that bus in order to boost voltage stability margin of the system under normal as well as contingency situation, minimise power losses, and raise loading parameter. The management of congestion aims to maximise social welfare and place SVC. Social assistance has been raised from 1700 to 2710 dollars per hour. Improved voltage levels, LMP, and line utilisation factor are also present. There is an increase in the maximum loading parameter from 1.04 pu to 1.86 pu.Real power loss is also lowered by 90.6% while reactive power loss is cut by 80.2%. This suggests improved congestion control, increased voltage stability, and the most dependable and cost-effective power system operating.

6 Reference

[1] Thom Patterson, “U.S. electricity blackouts skyrocketing,” CNN, August 9, 2010 7:36 a.m. available at http://edition.cnn.com/2010/tech/innovation/08/09/smart.grid/index.html.

[2] National Electricity Policy, 12-Feb-2005 available at http://www.powermin.nic.in/ whats_new/national_electricity_policy.htm

[3] N. G. Hingorani, “Introducing custom power,” IEEE Spectrum, vol. 32, No. 6, pp. 41-48, June 1995.

[4] B. Singh, “Induction generator – A prospective,” Elect. Mach. Power Syst., vol. 23, pp.163-177, 1995.

[5] G. K. Singh, “Self-excited induction generator research – a survey,” Electric Power System Research, vol. 69, no. 2-3, pp. 107-114, May 2004.

[6] R. C. Bansal, “Three Phase self excited induction generator: an overview,” IEEE Trans. on Energy Conversion, vol. 20, no.2, pp. 292-299, June 2005.

[7] R. C. Bansal, T. S. Bhatti and D. P. Kothari, “Bibliography on the application of Induction Generator in Non-Conventional energy systems,” IEEE Trans. on Energy Conversion, vol. EC-18, no.3, pp. 433- 439, Sept. 2003.

[8] D. B. Watson and I. P. Milner, “Autonomous and Parallel operation of self excited induction generator,” International Journal of Electrical Engineering Education, vol.22, pp. 365-374, 1985.

[9] E. G. Marra, and J. A. Pomilio, “Self-excited induction generator controlled by a VSPWM bi-directional convertor for rural applications,” IEEE Trans. on Industry Applications, vol. 35, no. 4, pp.877-883, July/ August 1999.

[10] R. Bonert and S. Rajakaruna, “Self–excited induction generator with excellent voltage and frequency control,” in Proc. Inst. Elect. Eng. Gen. Transm. Distrib., January 1998, vol. 145, No.1, pp.33-39.

[11] E. Suarez and G. Bortolotto, “Voltage – Frequency control of a self excited induction generator,” IEEE Trans. Energy. Convers., vol. 14, no.3, pp. 394- 401, Sept.1999.

[12] J. M. Ramirez and E.Torres M., “An electronic load controller for the

self-excited induction generator," IEEE Trans. Energy Conversion, vol. 22, no. 2, pp. 546-548, Jun.2007.

[13] B. Singh, S. S. Murthy and S. Gupta, "Transient analysis of self excited induction g enerator with electronic load controller supplying static and dynamic loads," IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1194-1204, Sept. 2005.

[14] B. Singh, S. S. Murthy and S. Gupta, "Analysis and design of electronic load controller for self excited induction generators," IEEE Trans. Energy Convers. Vol. 21, no. 1, pp. 285-293, Mar. 2006.

[15] B. Singh, S. S. Murthy and S. Gupta, "A Voltage and Frequency Controller for self excited induction generator," Elect. Power Compon. Syst. Vol. 34, no. 2, pp. 141-157,Feb 2006.

[16] J. A. Barrado and R. Grino, "Voltage and Frequency control for a self excited induction generator using a 3-phase 4-wire electronic converters," in Proc. 12th Int. IEEE Power Electronics Motion Control Conf. Aug. 2006, pp. 1419-1424.

[17] B. Singh, S. S. Murthy and S. Gupta, "STATCOM based voltage regulator for selfexcited induction generator feeding non-linear loads," IEEE Trans. Ind. Electron. Vol. 53, no. 5, pp. 1437-1452, Oct. 2006.

[18] B. Singh, S. S. Murthy and S. Gupta, "Analysis and Design of STATCOM based voltage regulator for self-excited induction generator," IEEE Trans. Energy Convers. Vol. 19, no.4, pp. 783-790, Dec. 2004.

[19] M. B. Brennen and A. Abbondati, "Static exciter for induction generator," IEEE Trans.Ind. Appl. Vol. 13, no.5, pp. 422-428, Sept. 1977.

[20] B. K. Bose, Modern Power Electronics and AC Drives, New Delhi: PHI Learning Pvt.Ltd. 2009.

[21] J. B. Dixit and A. Yadav, Electrical Power Quality, University Science Press, Laxmi Publications Pvt. Ltd. New Delhi, 2010.

[22] R. S. Vedam and M. S. Sarma, Power Quality and var compensation in Power System, CRC Press, NY, 2009.

[23] E. F. Fuchs and M. A. S. Masoum, Power Quality in Power Systems and ElectricalMachines, Elsevier Inc. 2008.

[24] F. C. De La Rosa, Harmonics and Power Systems, CRC press, FL, 2006.

[25] Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems

Rated 1kV through 38kV, IEEE P1409 Distribution Custom Power Task Force, 2003.