A HIGH-PERFORMANCE SPWM CONTROLLER FOR THREE-PHASE UPS SYSTEMS HIGH NONLINEAR LOADS

1SHARAD B BHOSALE, 2A SHRAVANKUMAR, 3CH. ANITHA, 4CH. MALLAREDDY

1PG Scholar, 2,3,4Professor, Dept of Electrical Engg., FTC Sangola, India.
E-mail: 1sharad.bhosale33@gmail.com, 2shravan249@gmail.com, 3chirra.anitha@gmail.com, 4mallaredy.chinnala@gmail.com

Abstract— This paper presents the design of a high-performance SPWM which stands for sinusoidal pulse width modulation controller for three phase uninterruptible power supply (UPS) systems that are operating under highly nonlinear loads. This SPWM method is not good enough in compensating the harmonics and the distortion caused specifically by the nonlinear currents drawn by the rectifier loads. This study proposes a new design strategy that overcomes the limitations of the classical RMS control. It adds inner loops to the closed-loop control system effectively that enables successful reduction of harmonics and compensation of distortion at the outputs. The simulations are done in the MATLAB/ SIMULINK environment using the Simulink and PLECS model of the inverter. The results are evaluated based on steady-state error, transient response, and the THD of the output voltage. A THD equal to 0.89% at the output voltage is achieved even under the worst nonlinear load.

Keywords— SPWM, UPS, MATLAB, Simulink.

I. INTRODUCTION

In the modern world, electricity has an indispensable role the difficulty in modeling the zigzag transformer and with its ability to combine power and intelligence. Most of uncertainty in the parameters of transformer, model based the systems which are located in critical points in daily life control algorithms which are the methods discussed in most need electricity to operate. The electrical energy increases papers, are not directly applicable to the transformer based productivity, efficiency, and allows a high degree of safety, UPS. Thus, instead of model based control structures, self-reliability, and comfort of life. Contingency in the electric converging feedback control structures are investigated. power line cannot be accepted critical areas involving safety. Among various control techniques, synchronous reference security, continuous industrial processes, data protection in frame control (SRFC), resonant filter type control (RFC), information technologies. Although in the past backup and repetitive control (RC) are found suitable for application generators were satisfactory to get power in case of to the transformer UPS. However, due to the complexity of interruption in the utility, long delay of generator starting the above techniques, only the multi-loop high-performance and switching in today is not acceptable. Such delays badly SPWM control strategy method is considered suitable for the affect critical loads such as computers, internet providers, low cost (in terms of control, measurement etc. cost) and/or telecom service providers, etc. as the power interruption high power UPS systems. Therefore, the multi-loop high causes data loss, process failure, and the cost for recovery performance SPWM and its application to the three-phase becomes unacceptable. Even though the electric utility transformer based UPS system will be the main focus of this industry has made great effort for uninterrupted power line paper. problems such as distortions, sag, swell, and spikes. In order The aim of the paper is to establish in depth background to avoid such problems, uninterruptible power supply (UPS) on the multi-loop control method and apply the knowledge systems [2]-[5], [7]-[36] with continuous and clean output to systematically design the output voltage controller of the power are utilized by compensating the harmonics and three-phase transformer based UPS. With the design issues distortions caused by specifically nonlinear loads by well understood and a proper design completed, the implementing certain suitable and efficient control performance of such a system will be investigated in detail techniques, with linear and non linear loads to evaluate the feasibility of In this paper, output voltage control of a UPS with a zig-advanced controller to control the output voltage to obtain zag connected transformer is investigated. Although there THD levels much less thereby improving the quality of exist many papers on the output voltage control of UPS, output delivered to the load. Therefore, the main minority of them involve the transformer based UPS. Due to contribution of this thesis is towards high performance multi-loop controller design and detailed performance investigation of a three-phase transformer based UPS system as shown in Fig.2. The stationary or synchronous-frame space-vector PWM (SVPWM)-based controllers are the primary choice of many researchers and the applications currently used in industry, today. However, the classical sinusoidal PWM (SPWM) method is still preferred by many manufacturers because of its implementation simplicity, easy tuning even under load, flexibility, and most importantly the advantages of controlling each phase independently and block diagrams shown in Fig.1.
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The independent regulation of each phase provides easy balancing of three-phase voltages which makes heavily unbalanced loading possible. Also, it avoids problems such as transformer saturation. Although the classical SPWM method is quite effective in controlling the RMS magnitude of the UPS output voltages, it is not good enough in compensating the harmonics and the distortion caused specifically by the nonlinear loads. For example, the total harmonic distortion (THD) is greater than 5% limit even with good filtering. It becomes more severe at high-power UPSs where the switching frequency has to be reduced due to the efficiency and heating problems. This study proposes a multi-loop high-performance SPWM control strategy and a design that overcome the limitations of the classical RMS control. It adds inner loops to the closed loop feedback control system effectively that enables successful reduction of harmonics and compensation of distortion at the voltages. The simulation results using the proposed controller achieves THD less than 3.0% under the nonlinear load having a crest factor of 3 and absorbing power equal to the rated power of the UPS. However, the significance of the proposed multi-loop controller compared to other methods is as follows:

The execution time is less and allows higher switching frequencies. The complex control algorithms take longer execution times and may limit the upper boundary of the switching frequency where you have actually some allowance for higher switching frequency operation [36]. Examples to the complex controllers are the repetitive, predictive, and harmonic droop controllers. The cost is low. Some control algorithms require precise floating point calculations either because they depend on a precise model or they use frequency-dependent sensitive controller gains. In brief, the precision dictates use of high-performance floating point expensive microcontrollers. The current implementation of the proposed controller is using fuzzy logic controller. The easy tuning even under load: Some are robust to this kind of tuning and some may not. This feature is preferred by some manufacturers. The easy tuning of the proposed method under load can be done with this method.

The flexibility: It means that you can modify your controller and optimize it according to the customer specifications at the time of installation or later in use. The optimization may include obtaining the lowest THD or the best tracking of the RMS value or the fastest dynamic response. So, the controller should be flexible anytime to do any of the aforementioned optimizations without significantly affecting the others. We have also verified this feature experimentally. The scalability: It means that the controller is easy to design and tunable for any power level. Accordingly, this paper favors the proposed multi-loop controller using fuzzy logic controller and presents the work according to the following arrangement. Section II provides a short description of a typical three phase UPS system.

**II. SIMULATION RESULTS**

The simulink model of the proposed multi-loop controller is built in Matlab simulation environment and performance is evaluated based on the RMS voltage and Total harmonic distortion (THD). The inverter power stage being heart of the UPS is being designed as sub circuit of the UPS and the state space model of the inverter that constitutes for stability is also designed and the control diagram is designed such that it is in line with the state space model of the inverter power stage of UPS.
III. EXPERIMENTAL RESULTS

A UPS system rated at 10 kVA, 50 Hz, 380 V was built and tested to evaluate the performance of the controller and the design. The implemented system uses the component values given in the PLECS simulation model of the converter shown in Fig.3 for the inverter part and the values given in Fig.2 for the controller part. In Fig.2, we compare the results of the multiloop design against the single-loop (only the RMS control) design in order to demonstrate the performance of the proposed multiloop controller. Fig.4 compares the measured three-phase output voltages and the current of one phase for two loading conditions: the linear full load and the nonlinear full load. Fig.5 show the results when only the RMS control is used (single-loop), for this case the control achieves 1.96% THD for the linear and 9.68% THD for the nonlinear load. It is clear that the RMS control alone cannot achieve an acceptable THD under nonlinear loading at the rated UPS output power.

The waveforms in Fig.6 show the results when the proposed multiloop controller is used for the same loading conditions. In this case, the controller achieves 1.11% THD for the linear load and 3.8% THD for the nonlinear load. The crest factor of the current in Fig.7 is measured as 2.8. The THD measurements given previously and also shown in Fig.8 were taken by the 3196 HIOKI power quality analyzer. The upper trace in Fig.9 shows the profile of the % THD of the output voltage of one phase versus the three different loading conditions: nonlinear full load, linear full load, and no load. The lower trace shows the total output apparent power delivered into these loads. The test was set up to supply each load approximately over a one-min interval. As shown in the lower trace of Fig.10, the UPS was initially loaded with the rated single-phase rectifier load, then no load, 1 min later a resistive load at 8.5 kW, and finally the same rectifier load is applied again in Fig.11.
Fig.9. RMS load voltage for linear loads.

Fig.10. RMS load voltage for non linear loads.

Fig.11. THD Analysis whose value is 2.85%.

CONCLUSION

This paper presents the analysis and design of a high performance SPWM controller for three-phase UPS systems powering highly nonlinear loads. Although the classical SPWM method is very successful in controlling the RMS magnitude of the UPS output voltages, it cannot effectively compensate for the harmonics and the distortion caused by the nonlinear currents drawn by the rectifier loads.

REFERENCES