NEW TOPOLOGY OF SHUNT HYBRID POWER FILTER FOR HARMONIC MITIGATION AND RE-UTILIZATION OF HARMONIC FILTER CURRENT AS USEFUL POWER

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We hereby declare that We have checked this thesis, and, in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Peranti elektronik kuasa telah banyak digunakan kebelakangan ini dalam sektor perindustrian, komersial dan peralatan rumah; ia termasuk penerus diod dan thyristor, bekalan kuasa mod beralih dan sistem pemacu kelajuaan boleh ubah. Apabila peranti-peranti ini disambungkan kepada grid, ia akan menghasilkan harmonik di dalam gelombang arus dan voltan dan ini akan menyebabkan kecekapan sistem berkurangan serta keseluruhan prestasi sistem merosot. Penapis kuasa pasif (PPF) konvensional yang digunakan untuk pengurangan harmonik mempunyai masalah, manakala penapis kuasa aktif (APF) tulen mempunyai kelemahan dari sudut kos dan penarafan yang lebih tinggi. Penapis aktif hibrid (HPF) mewarisi kecekapan PPF dan prestasi APF yang lebih baik; disebabkan itu ia membentuk pendekatan yang berdaya maju untuk pampasan harmonik. Lapan topologi HPF yang berbeza terdiri daripada satu APF dan PPF secara bersiri atau shunt atau gabungan. Di antara ke semua HPF mitigasi yang sedia ada, Shunt LC HPF didapati paling berkesan untuk mengatasi masalah harmonik kerana kebolehlak sanaannya untuk pampasan arus harmonik. Akan tetapi, ia tidak dapat melaksanakan pampasan kuasa reaktif dinamik yang memuaskan kerana kuasa reaktif yang berbeza dari semasa ke semasa. Tambahan pula, kapasitor penapis perlu berskala besar untuk mempunyai impedans rendah pada frekuensi tinggi yang akan dipengaruhi secara serius oleh sumber induktor. Kajian ini memperkenalkan topologi baharu shunt RLC-HPF untuk meningkatkan kecekapan pengurangan harmonik semasa dan melakukan pembetulan faktor kuasa (PF) melalui pampasan kuasa reaktif dengan penyediaan laluan impedans rendah melalui induktor (untuk frekuensi rendah) dan galangan rendah melalui kapasitor (untuk frekuensi tinggi. Keberkesanan HPF bergantung sepenuhnya pada kecepatan dan ketepatan pengesanan arus harmonik rujukan, peraturan voltan kapasitor pautan DC, dan kawalan arus yang dapat dicapai. HPF shunt telah direka berdasarkan strategi rangka rujukan segerak (SRF) dan penapis penalaan kendiri (STF) untuk membangunkan operasi penapis di bawah keadaan sumber voltan yang tidak ideal (tidak seimbang). Bagi pengawalnya, isyarat pensuisan untuk memacu penyongsang sumber voltan (VSI) pengawal arus histeresis adaptif APF shunt (AHCC) digunakan. Selain itu, pengawal rangkaian neural proportional-integral (PI) dan back propagation neural network (BPNN) dibangunkan untuk mengekalkan voltan malar merentasi kapasitor pautan DC supaya APF shunt boleh menyuntik dengan tepat arus yang dirujuk semula ke dalam sistem kuasa harmonik. Prestasi HPF shunt disahkan untuk semua kemungkinan keadaan sumber dan beban melalui simulasi MATLAB/Simulink. Keputusan simulasi yang diperolehi oleh strategi STF -SRF dengan pengawal BPNN menunjukkan pencapaian cemerlang jika dibandingkan dengan SRF dengan pengawal PI dalam pengurangan harmonik semasa, peningkatan PF, dan peraturan voltan DC. Hasilnya, nilai herotan harmonik jumlah minimum (THD) arus sumber merekodkan kelebihan jelas strategi STF-SRF (1.8%) berbanding strategi SRF sedia ada (10%), terutamanya dalam menangani keadaan voltan sumber yang tidak ideal. Tambahan pula, penemuan yang memberangsangkan telah membawa kepada pembetulan PF kepada 0.999 menggunakan STF-SRF berbeza dengan 0.842 dengan strategi SRF. Selain itu, voltan kapasitor pautan DC dikawal dan dikekalkan dengan betul pada nilai yang dikehendaki di bawah semua kes dengan pengawal BPNN, manakala pengawal PI gagal dikawal. Secara mutlaknya, matlamat utama topologi HPF baharu ialah penambahbaikan PF dan mengurangkan arus harmonik, serta penggunaan semula arus penapis harmonik yang diekstrak melalui penukaran kepada kuasa berguna untuk menyalurkan beban RL dalam had IEEE-519 - piawaian 2014

ABSTRACT

Power electronic appliances are recently used widely in industrial, commercial, and home sectors; these appliances include diode and thyristor rectifiers, and variable speed drive systems. When these appliances are connected to the grid, they generate harmonics in the current and voltage waveform which contributes to the degradation of the system efficiency and deterioration of the overall system performance due to an increase of effective peak value and also the rms current in some devices. Conventional passive power filters (PPF) for harmonic mitigation have inherent problems, while purely active power filters (APF) have the disadvantages of higher costs and ratings. Hybrid active filters (HPF) inherit the efficiency of PPFs and the improved performance of APFs, and thus, constitute a viable improved approach for harmonic compensation. An eight different HPF topology is composed of one APF and PPF in series or shunt or combination. Nevertheless, among the existing mitigation HPFs, the shunt LC HPF is the most effective against current harmonics problems due to its feasibility for harmonic current compensation. However, it cannot perform satisfactory dynamic reactive power compensation because reactive power varies from time to time. Furthermore, to have low impedances at high frequencies, the capacitor of this filter needs to be large which will be influenced seriously by the source inductor. In this study, a new topology of shunt RLC-HPF is introduced to improve the efficiency of current harmonic reduction and perform power factor (PF) correction through reactive power compensation via the provision of a low impedance path through the inductor (for low frequencies) and low impedance through the capacitor (for high frequencies).. The effectiveness of HPF is strictly dependent on how quickly and accurately the detection of reference harmonic current, DC-link capacitor voltage regulation, and current control is achieved. The shunt HPF was designed based on synchronous reference frame strategy (SRF) and self-tuning filter (STF) to develop the operation of the filter under non-ideal (unbalanced and/or distorted) source voltage conditions. As for its controller, switching signals to drive the voltage source inverter (VSI) of the shunt APF adaptive hysteresis current controller (AHCC) are used. Also, proportional-integral (PI) and back propagation neural network (BPNN) controllers are developed to maintain a constant voltage across the DC-link capacitor so that the shunt APF can precisely inject the desired referred currents back into the harmonic power system. The shunt HPF performance is validated for all possible conditions of source and load by simulation using MATLAB/ Simulink environment. The simulation results obtained by the STF -SRF strategy with BPNN controller showed excellent achievement when compared to SRF with PI controller in the mitigation of current harmonics, PF enhancement, and DC voltage regulation. As a result, the minimum total harmonic distortion (THD) values of the source current recorded clear advantages of the STF-SRF strategy (1.8 %) over the existing SRF strategy (10 %), especially in dealing with non-ideal source voltage conditions. Furthermore, the encouraging findings have led to the correction of the PF to 0.999 using STF-SRF in contrast to 0.842 with the SRF strategy. Moreover, the DC-link capacitor voltage was properly regulated and maintained at the respective desired values under all cases with the BPNN controller, while the PI controller failed to be regulated. Ultimately, the main aim of the new HPF topology is the improvement of PF and reducing harmonic current, as well as re-utilization of the extracted harmonic filter current via conversion to useful power to feed the RL load within the limitation of the IEEE-519-2014 standards.

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