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Review Paper

Power Quality Improvement of Power Electronics Systems by using Machine Learning

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Abstract

The power electronic components or devices are the main focus of this report. It gains more popularity because of its reduced size and smooth control on output voltage & current. It is very popular in areas of renewable energy sources (as converters & inverters) and industrial drives (as controlling devices). In both cases, the power electronic components and devices act as non-linear loads due to its switching process. This causes system to generate the harmonics or cause of power quality problem. This should be mitigated or eliminated by using different methods, recommended by some standards e.g. IEEE-519. The limits and guidelines are also given by them to help the customers and manufacturers. The improvement in power quality can be achieved by Machine learning algorithms. Machine learning is another very popular area, which uses the data of any system and predicts the system output after training the model (e.g. for classification of fault type and identification of exact location of faults, predicting the life of power electronics components, detection of voltage disturbances). Depending on different techniques of machine learning, different applications can be achieved.

Keywords: Filters, Semiconductor Devices, Non-Linear Loads, Harmonics, Power quality improvement, Machine Learning.

Introduction

The increasing population requires more energy to consume or facilitate the lifestyle. Also, there is fast reduction in fossil fuels, which are the main sources of energy (i.e. coal, diesel, petrol etc.). The alternate sources are needed, e.g. solar energy, wind etc.

Now, the aim should be to extract more electrical energy from the source i.e. to make more efficient system. So, the power electronic converters are used in these systems. It is efficient but introduces harmonics in system. There are many methods to mitigate or eliminate the harmonics and other power quality problems.

Machine learning can also be used to find the solution of power quality problems. There are many papers discussed here, which explain the different methods of machine learning. Some methods are given as the best suitable method for particular applications.

Qualification Enhancement is the requirement in my profession. Hence, this literature review research work is also being done with the intentions of registration towards Ph.D. program.

Literature Review: An improved control algorithm of shunt active filter for voltage regulation, harmonic elimination, power-factor correction, and balancing of nonlinear loads described a new control algorithm for a three-phase shunt active filter to regulate load terminal voltage, eliminate harmonics, correct supply power-factor, and balance the nonlinear unbalanced loads. AF has an inherent property to provide a self-supporting dc bus and requires less number of current sensors resulting in an overall cost reduction[1].

Mitigation of Harmonics in Voltage and Current Using UPQC described about Voltage and current harmonics on source side eliminated drastically by using UPQC.

This makes easy to achieve the highest power capacity along with maximum efficiency of the supply, and minimum deviation to other devices will be ensured[2].

An improved control algorithm for active filters described a new control algorithm resulting in significant advantages toward smooth control of an active filter (AF). Notches and distortion-free supply currents during steady and transient operating conditions of the nonlinear load and reduced switch topology of the AF systems and prevents the flow of harmonics and reactive power from supply to load[3].

A review of three-phase improved power quality ac-dc converters described a comprehensive review of improved power quality converters (IPQCs) configurations, control approaches, design features, selection of components, other related considerations, and their suitability and selection for specific applications.

IPQCs provide improved power quality not only at the input ac mains but also at dc output for the better overall design of equipment[4].

A Review of Active Filters for Power Quality Improvement described a comprehensive review of active filter (AF) configurations, control strategies, selection of components, other related economic and technical considerations, and their selection for specific applications. It presents overall review on AF[5].

Selective compensation of power-quality problems through active power filter by current decomposition described the decomposition the load current into positive and negative sequence fundamental frequency active components, reactive component and harmonic components in synchronous reference frames. The control scheme performs with priority-based scheme, which respects the limited rating of the APF Selectively compensate the current harmonics, unbalanced loading and reactive power, based on priority to respect the limited power capacity of the VSI. A fast response and is able to maintain near sinusoidal source current for harmonic compensation conforming to IEEE-519 standard and is able to self support the dc bus[6].

A python based power electronics e-learning tool gave a collection of software programs that can be useful in the teaching process of power electronics and electrical drives. This provides more flexible and cheaper than actual laboratory arrangements[7].

Review of Internet of Things (IoT) in Electric Power and Energy Systems described the digitizing the electric power ecosystem using IoT improves asset visibility, optimal management of distributed generation, eliminates energy wastage, and create savings can evolve an intelligent IoT system by emulating biological nervous systems with cognitive computation, streaming and distributed analytics including at the edge and device levels[8].

Instantaneous Reactive Power Compensators Comprising Switching Devices without Energy Storage Components described a new instantaneous reactive power compensator comprising switching devices is proposed which requires practically no energy storage components. This compensator can eliminate not only the fundamental reactive power in transient states but also some harmonic currents caused by the instantaneous imaginary power[9].

Robust Control of Interconnected Power Electronic Converters to Enhance Performance in dc distribution systems: A case of study" described the design and evaluation of robust controllers, based on linear programming, Kharitonov's theorem and Chebyshev's theorem, in order to enhance the performance of a typical structure of multi-stage converters present in direct current (dc) systems. This concludes K-Robust control showed better dynamic behaviour, such as minor overshoot and fast transient response[11].

The Impact of VSFPWM on DQ Current Control and a Compensation Method described a prediction model to reduce the switching losses and lower the electromagnetic interference (EMI). A compensation method is also described for the varying phase lag in output voltages[13].

Design, simulation and implementation of three-pole/four-pole topologies for active filters described Three-pole/four-pole topologies of current-controlled voltage source inverters (CC-VSI) used as active filter (AF) demonstration its effectiveness for harmonic elimination, reactive power compensation and power-factor correction.

Artificial Neural Network (ANN) Based Fast and Accurate Inductor Modeling and Design analyze the potential of Artificial Neural Networks (ANNs) for the modelling and optimization of magnetic components and, specifically, inductors. It demonstrates how machine learning can be combined with classical power electronic models in order to improve their accuracy and reduce the computational cost[14].

Methodology

Electric power quality has become an important part of power systems and electric machines. Various sources use the term power quality with different meaning. It is used synonymously with supply reliability, service quality, voltage quality, current quality, quality of supply, and quality of consumption.

Some references divide the distortion sources into three categories: small and predictable (e.g., residential consumers generating harmonics), large and random (e.g., arc furnaces producing voltage fluctuations and flicker), and large and predictable (e.g., static converters of smelters and high voltage DC transmission causing characteristic and uncharacteristic harmonics as well as harmonic instability). However, the likely answers to the question are these: unpredictable events, the electric utility, the customer, and the manufacturer.

Nonlinear loads produce harmonic currents that can propagate to other locations in the power system and eventually return back to the source. Therefore, harmonic current propagation produces harmonic voltages throughout the power systems. Many mitigation techniques have been proposed and implemented to maintain the harmonic voltages and currents within recommended levels: i. High power quality equipment design, ii. Harmonic cancellation, iii. Dedicated line or transformer, iv. Optimal placement and sizing of capacitor banks, v. De-rating of power system devices, and vi. Harmonic filters (passive, active and hybrid) and custom power devices such as active Power line conditioners (APLCs) and unified or universal power quality conditioners (UPQCs).

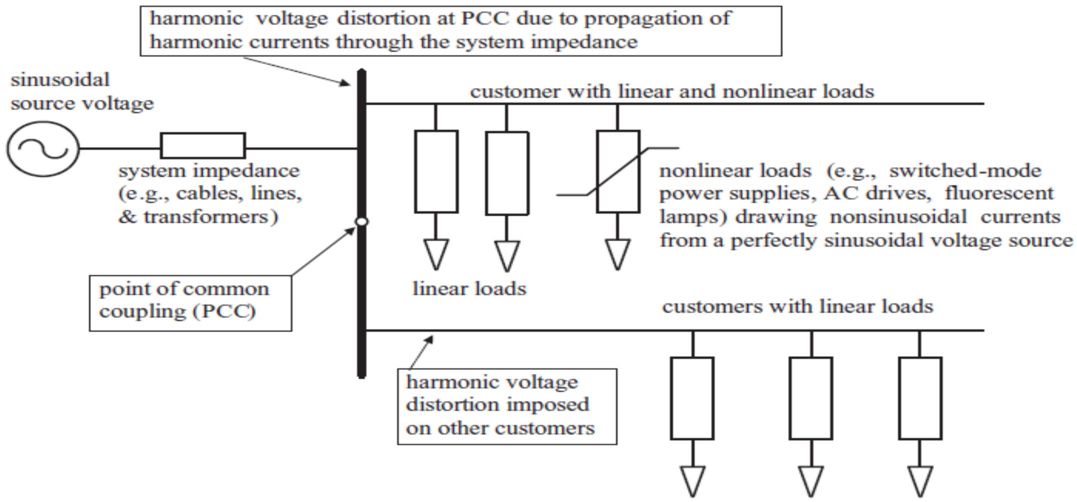

Figure-1: Propagation of harmonics (generated by a nonlinear load) in power systems[32].

Machine learning is quickly gaining popularity in last decade and it found its application in many fields including in Electrical power systems[10,12]. There are some successful research work which indicates that by using Machine learning, there is new hope and chance to improve the overall performance of Electrical Power system.

Conclusion

This paper concludes that use of power electronic systems distort the waveforms of system. It further reduces the power quality of system. There are existing power quality improvement techniques. There is some research works which uses machine learning for this purpose. This paper is a consolidated form of review of some research papers on the above matter.

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