

End Game Algorithm Based Scalable Inverters and Its Application in Microgrid

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ABSTRACT: Scalable inverters (SI) are prime components of distributed generation systems and micro-grid, because they are used to integrate the renewable energy resources to the utility grid. Recently these kinds of inverters have captivated more and more attention for their aid on ancillary services on power quality enrichment in micro-grids. The main objective is to compensate the harmonic and reactive current. In this paper, the excellent control objectives of scalable inverters are presented based on end game algorithm by means of Comprehensive Power Quality Index (CPQI) and Analytical Hierarchy Process (AHP).

KEYWORDS: micro-grid, end game algorithm, scalable inverter, Comprehensive Power Quality Index, Analytic Hierarchy Process.

I. INTRODUCTION

A micro-grid is a combination of loads and micro-sources operating as a single controllable system that affords power to its local area. To the utility, the micro-grid can be thought as a single controllable load that can respond in seconds to meet the urge of the transmission system. Whereas to the customer, the micro-grid can meet their special requirements such as enhancing local reliability, reducing feeder losses, supporting local voltages, providing increased efficiency through the use of waste heat, voltage sag correction or providing uninterrupted power supply. Radically, a micro-grid is considered as a power resource to minimize the power fluctuation of Renewable Energy Resources (RES). The micro-grid provides active and reactive power to the utility in order to enhance the stability of the system. Moreover, due to its flexibility of operating modes in both grid connected and islanding modes, the micro-grid can enhance the operation and control of the utility. Power quality issue is a major concern in a micro-grid due to the distinct non-linear and reactive loads. The harmonic resonance induces some cascading failure in the system. The harmonic and reactive current flow give rise to power loss and also end with noise and vibrations in transformers and electrical machines. The poor on-grid price in electricity market is due to poor power quality. Scalable inverter can greatly save capital investment and system space, because the various functionalities of multiple devices such as active power filter, static var compensators etc. are implemented in the same equipment. In general, the overall capacity of scalable inverter is greater than that of installed photo voltaic arrays and wind turbines. Thus the excess capacity of scalable inverter is utilized to enrich the power quality, in such condition additional power quality conditioner need is bypassed.

II. THE PICTURE OF A MICRO-GRID AND THE SCALABLE INVERTER

A) *OUTLINE OF THE MICRO-GRID*

“It is particularly a portion of an electric power distribution system located downstream of the distribution substation. “ as in [1].

“Distributed energy resources (DER) refer to both DG and energy storage technologies. Generation technologies applicable for micro-grid may include emerging technologies (Combined heat and power (CHP), fuel cells, mini

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wind turbines, PV, micro-turbines. The available energy storage technologies batteries, fly-wheels and super capacitors are more applicable for micro-grid type of setup Most of the emerging (DER) technologies require an inverter interface in order to convert the energy into grid compatible ac power.” as in [1].

Solar energy is considered one of the most encouraging energy sources due its immense power. The word photo voltaic means direct conversion of sunlight into electricity by means of solar cells. A photovoltaic cell is a semiconductor device that converts light to electrical energy by photovoltaic effect.

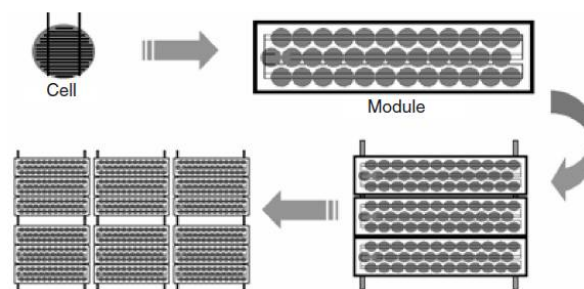


Fig.1. Photovoltaic cells, modules, panels & array.

If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from photodiode. In photodiode light falls on channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased. Fig.1.photovoltaic cells, modules, panels and array, as in [8].

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of module whereas the parallel connection is responsible for increasing the current in the array.

Wind energy is converted into useful form of energy using wind turbines is called wind power. Wind is abundant almost in any part of the world. The cost of wind power is cheaper compared to the cost of generating electricity using coal and oil. The most important factors that contribute to the efficiency of wind turbine are wind speed and rotor blade. The key factor for the successful operation of wind farm is the ability to regulate voltage at the point of common coupling, as in [9].

B) OUTLINE OF THE SCALABLE INVERTER

The grid connected inverters are classified as single stage (DC/AC stage) and multi stage (DC/DC & DC/AC stages). The important factor to be considered in grid connected scalable inverter is its high efficiency and low cost. Single stage inverter uses few electronic components, and has a smaller bulk, higher efficiency, low cost and high reliability. Hence single stage scalable inverter is implemented in thispaper. Based on the control schemes, Current Controlled Voltage Source Inverter (CCVSI) is considered because the current generated by them can be controlled from AC voltage. The major reason is unity power factor operation for the whole range of load. With the aid of Proportional Resonant controller, IGBT pulses are obtained from the Sinusoidal Pulse Width Modulation (SPWM).

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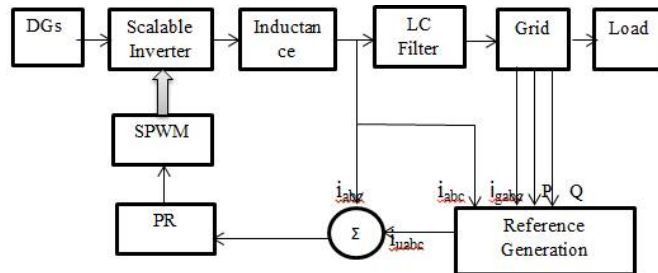


Fig.2. Topology of scalable inverter.

From Fig.2 it can be seen that scalable inverter samples its output current i_{abc} and the grid current i_{gabc} . In order to calculate the reference current i_{uabc} end game algorithm is used.

III. OPTIMAL COMPENSATION OF SCALABLE INVERTER

C) COMPREHENSIVE POWER QUALITY INDEX

In conventional power quality conditioners, the harmonic and reactive current is compensated by providing equal weight. Where as in scalable inverter, the harmonic and reactive current is distinguished using different contributing weights, based on comprehensive power quality index.

There are different methods available to calculate the weights of power quality indices. However for enhanced analysis, subjective fuzzy method is used because this method is simple, accurate and less time consuming. Two different power quality indices are taken and related with one another. The priority matrix is developed based on ‘‘Satty’s1-9 scale’’ as in [4]. In this paper, harmonic issue has given more importance compared to reactive current issue.

With reference to the AHP based comprehensive power quality index model, the power factor and harmonic has different contributing weights a_1 and a_2 , as in [2].The order of priority matrix is 2. Eigen value and eigen vectors are calculated for priority matrix whose maximum eigen value is 2. The weight of two power quality indices is $a=(a_1,a_2)=(0.75,0.25)$.

Based on AHP theory consistency index (CI) has to be zero, as in [4],[2]

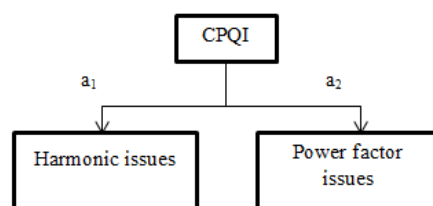


Fig.3. CPQI evaluation of power quality issues.

Fig.3. is the representation of power quality issues based on CPQI technique, as in [2]. Fig.2. implies the topology and overview control strategy of scalable inverter along with DGs and loads.

D) CONTROL STRATEGY OF SCALABLE INVERTER

In general, three phase inverters are normally used for high power applications. Two types of control signals can be applied to the transistors: 180° or 120° conduction. Utilization of switches is better in 180° conduction, hence it is preferable method. Each transistor conducts for 180° . There are six modes of operation in a cycle and the duration of each mode is 60° . The transistors are numbered in the sequence of gating the transistors (123, 234, 345, 456, 567 and 612), as in [7]. The switches of any leg of the inverter cannot be switched on simultaneously. The sinusoidal PWM is a carrier based PWM technique, which defines the on and off states of the switches by comparing the carrier voltage and

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the output voltage. To avoid the failure of decoupling control in synchronous rotating dq frame, the current tracking is performed in abc frame using PR controller..

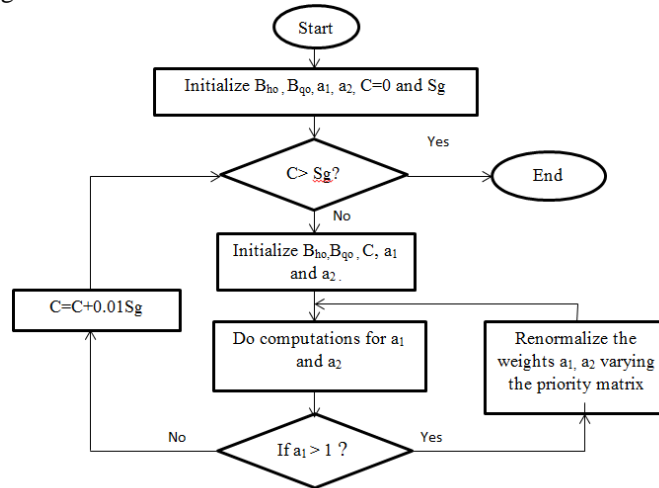


Fig. 4. Flow chart of optimal compensation.

E) END GAME ALGORITHM TO GENERATE THE REFERENCE CURRENT.

The reference current has two parts. One is used to interface renewable energy resources into utility and the other is used to compensate the power quality issues especially harmonic and reactive current in the micro-grid. The implementation of algorithm on a DSP control board is easy when we generate reference current in non-phase locked loop.

Initially grid voltage, grid current and output current is measured and converted into dq frame from abc frame. This conversion is made to make the analysis simple. The converted voltage and current measurements are deployed into active and reactive components. The observed reactive and harmonic equivalents is multiplied by the optimal compensation coefficient, namely α_1, α_2 is added to the reference active and reactive power of renewable energy resources. Then the resultant current is again converted back to abc frame.

According to the analysis, flowchart to obtain the optimal compensation is shown in Fig.4, as in [2]. Here B_{ho}, B_{qo} are the initial harmonic and reactive coefficients before compensation. Based on PQ standards consider the value of C as zero, because smaller C gives better power quality. S_g is calculated based on initial harmonic, reactive component and their weightage.

F) SIMULATION RESULTS

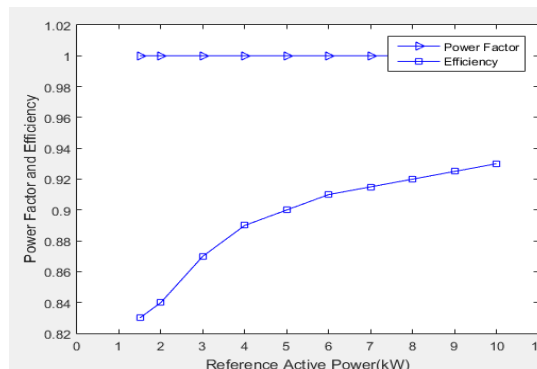


Fig.5. Response of scalable inverter to the power factor.

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As current generated from CCVSI can be controlled independently from AC voltage, the active and reactive power controls are decoupled. Not only is that, due to PR control technique unity power factor achieved.

Unity power factor is maintained by fixed phase delay with respect to grid voltage. Fig.5. indicates the power factor in the system.

Fig.5, 6 shows the enhancement of power quality issue especially the total harmonic distortion and power factor.

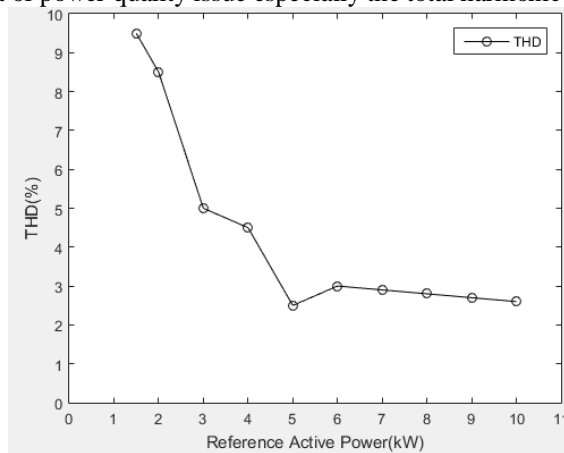


Fig.6. performance of scalable inverter in power quality enhancement.

Fig.7. shows the performance of the system with respect to end game algorithm based scalable inverter, before compensation and after compensation.

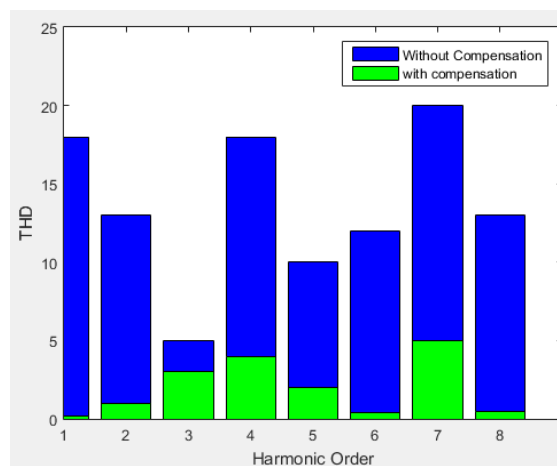


Fig.7. Response of the scalable inverter to the harmonic distortion.

Fig.8. shows the end game algorithm based compensation of the scalable inverter and their alpha values .

A part of the overall capacity of the scalable inverter is used to compensate the power quality issues in the point of common coupling of DGs.

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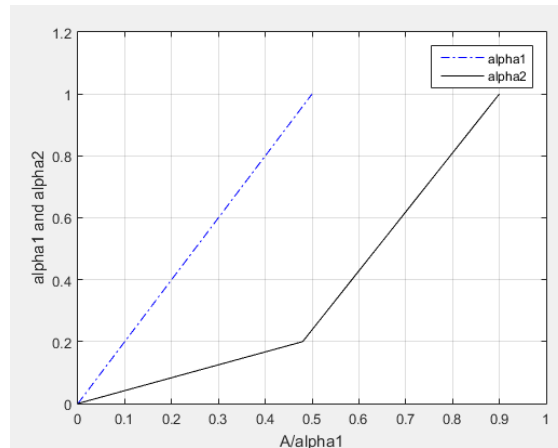


Fig.8. Optimal compensation of scalable inverter.

The compensation is based on CPQI technique which is simple and easy to carry out the power quality issues in the system.

IV. CONCLUSION

The scalable inverter is used to compensate the power quality issues efficiently compared to the conventional inverters. Generally, inverters are used to interface the renewable energy resources into utility. The excess capacity of the inverter is used here to compensate some power quality issues as an ancillary service

In conventional power quality conditioners, the harmonic and reactive current is compensated by providing equal weight. Where as in scalable inverter, the harmonic and reactive current is distinguished using different contributing weights, based on comprehensive power quality index.

These type of inverters save the capital investment and system space. It also improves the stability of utility by injecting the proper active and reactive power.

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