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A Novel Approach of Power Quality Improvement Using UPQC Along With Microgrid

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Abstract : The micro-grids are the interconnection of renewable resources available at the distribution side. Micro -grids can be operated in three different ways such as, grid connected mode, autonomous mode and micro generation mode. Solar panel, wind energy and battery are connected as source for integration of DG based grid connected microgrid system. Battery Energy storage system can store the energy and can be delivered to local load when solar or wind power is low. The environmental factors along with variations in load, capacitor switching, charging of transformers and use of nonlinear loads are lead to Power Quality problems such as sag, swell, harmonics, etc. To eliminate these power quality issues from the integration of DG based grid connected microgrid system, Unified Power Quality Conditioner (UPQC) is used. DG converters (with storage), the load and shunt part of the UPQC will be located after the PCC. The series part of the UPQC will be located before the PCC and in series with the grid. DC link can be connected to the storage system also. The UPQC is used to balance the voltage sags /swells, harmonic and reactive power compensation in the interconnected mode. The DG Converter along with storage can supply the active power and the shunt part of the UPQC can compensate the reactive power and harmonic power of the load during the islanding mode. The new control strategy is used for the integration and control of Unified Power Quality Conditioner in distribution generation based micro-grid system is simulated in MATLAB/Simulink model using Decision tree algorithm.
Keywords : Distribution Generation, DT algorithm, Islanding Detection, Microgrid, Power Quality, Synchronous reconnection, Unified Power Quality Conditioner.

Introduction

Recently, distributed generation (DG) has become widely used because of the advantages associated with this green form of energy[1].Wind energy and photovoltaic (PV) systems are eco- friendly and considered as primary energy resources for the future. However, high DG penetration offers technical and operational challenges, causing power quality (PQ) and stability problems. Output stability is a prime concern when systems operate in an isolated or grid-connected mode as per the requirements.

The behaviour of the PV system is influenced by various factors, including solar irradiation and the temperature of the cell. Similarly, wind energy systems depend upon the input wind speed, tower shadow effect. These environmental factors along with variations in load, capacitor switching, charging of transformers, starting of induction machines, use of nonlinear loads, and welding transformers lead to PQ problems such as sag, swell, harmonics, etc. This includes mal-operation of protective devices, failure and overloading of electrical equipment, instabilities, and so on [14.] For example, when wind/PV systems are interfaced to the grid with the help of dc/dc and dc/ac converters, and maximum power point tracking controllers are included into these systems, system complexity increases further to deal with PQ problems.

To extend the operational flexibility and to improve the power quality in grid connected microgrid systems, a new control approach of placement and incorporation technique of UPQC have been proposed in[3], which is termed as UPQCμG. In the UPQCμG integrated distributed system, micro grid (with storage) and shunt part of the UPQCμG are placed after the Point of common coupling. The series of the UPQC is placed before the Point of common coupling and in series with the grid. DC link is connected to the storage.

To maintain the operation in island mode and reconnection through the UPQC, communication process between the UPQC micro grid and micro grid system is mentioned in[3]. In the present work, the control method of the presented UPQC micro grid in[3] is improved by implementing an islanding and novel reconnection technique with reduced number of switches which will ensure smooth operation of the micro grid without disturbance. The objective of this paper is to study the various types of power quality problems and their effects in distribution generation based grid coupled microgrid system. Construct the micro grid control for all modes of operations, with more importance on voltage sag voltage swell, harmonic and reactive power compensation and active power transfer to the load during the interconnected mode and how they can be mitigated with the use of the Unified Power Quality Conditioner (UPQC) using decision tree algorithm.

In this paper Different power quality issues their causes and consequences and solution have been discussed with islanding and reconnection technique. The modeling of series APF, shunt APF, Islanding detection and Reconnection and the UPQC has been carried out .Using decision tree algorithm the model has been developed. DT is selected because of its classification ability with higher accuracy. From the simulation results UPQC improves the power quality of power system during sag, swell and interruption situation with islanding condition. The THD of the source current and load current will reduce. Insection II, the block diagram of proposed scheme system is introduced. In section III, the detailed explained of proposed system is discussed. In section IV, simulation results are performed to analyse the DG condition and its effect of load sharing. Finally, conclusions are drawn in section V.

II. Proposed Block Diagram

Fig.1 shows the block diagram of the proposed system which consists of three main parts such as grid, load and microgrid system. In addition to that, the DG link is integrated to the network by means of UPQC. Three sources are considered as microgrid system such as PV system, wind energy system and battery. To have high efficiency in PV cell, incremental conductance MPPT algorithm is used. The boost converter is used to boost DC voltages from PV cell. In wind energy system, AC to DC converter is used. A breaker is used to connect or disconnect the battery. Then the outputs of these three sources are used to convert to AC voltage by means of three phase three level inverter.

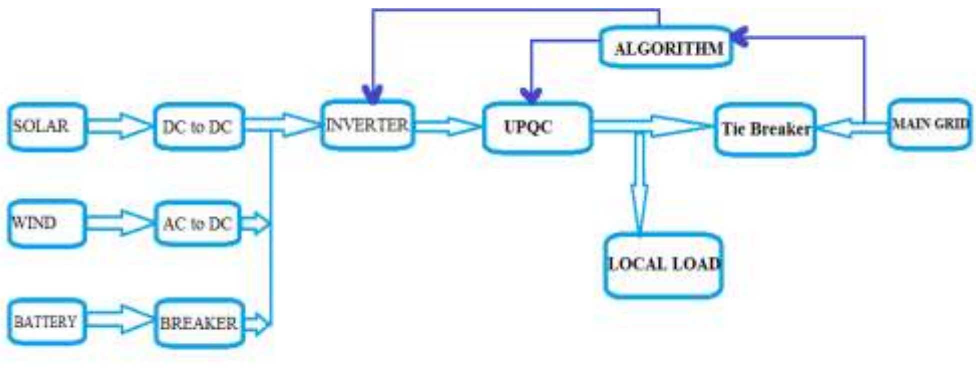

Fig.1 Block diagram of proposed system

Unified Power Quality Conditioner (UPQC) is integrated in DG based grid connected microgrid system using decision tree algorithm. DG converters (with storage), the load and shunt part of the UPQC will be located after the PCC. The series part of the UPQC will be located before the PCC and in series with the grid. DC link will be connected to the storage system also.The UPQC is used to compensate the voltage sags /swells, harmonic and reactive power compensation during the interconnected mode. The DG Converter along with storage will supply the active power only and the shunt part of the UPQC will compensate the reactive and harmonic power of the load in the islanding mode. DT can compare the voltage and current values simultaneously, which are from PCC. Select the choice of attributes and send the signals to UPQC.

III. Proposed control scheme

The general integration technique and control approach are used to improve the quality of power during interconnected and islanded modes. This technique involves detecting islanding and reconnection to secure the DG converter remains coupled and deliver active power to the load. This reduces the control intricacy of the converter as well as the power failure opportunity in the islanded mode. The key Controllers of the proposed system are

- Series part Control (APFse)
- Shunt part Control (APFsh)
- Intelligent Islanding Detection
- Synchronization and Reconnection

Because of the Islanding detection and Synchronous Reconnection features are new in UPQC therefore; these have been presented in details.

A. Intelligent Islanding Detection (IsD)

Micro grid operation in connection with the distribution grid, it has a capability of (i) maintaining connection during grid fault condition, (ii) identifying and detecting the islanded condition automatically and (iii) recoupling after the grid fault. These are the most important features of the micro grid system. In that case, the placement of APFse in the proposed coupling method of the system plays an important task by improving the operational flexibility of the DG converter in the microgrid system.

In addition to the islanding detection, varying the control policy from current to voltage control may result in severe voltage problems and it becomes serious when it is delayed in the case of hierarchical control. Therefore seamless voltage transfer control among the grid-connected and isolated controlled modes is very important to mitigate the voltage transients in transition mode, but it will increase the control complexity of the microgrid converters.

In the case of power quality problems, it is reported that more than 95% of voltage sags can be compensated by injecting a voltage capable of 60% of its nominal voltage, with the duration of 30 cycles. The series active power filter takes the responsibility for compensating voltage sag/swell/unbalance disturbances. The voltage at the pcc is considered as the reference and it is always in phase along with the source and the DG converters, the difference between the Vpcc-ref (pu) and Vs (pu) is Verror. This Verror is then compared with the pre-set values (0.1 to 0.9) and a waiting period (user defined n cycles) .It is used to determine the voltage sag/interrupt/islanding condition.

B. Synchronization and Reconnection

When the grid system is restored, the micro grid may be reconnected to the main grid and return to its pre-disturbance condition. A seamless reconnection can be achieved when the difference between the magnitude of voltage, phase angle and frequency of the two buses are minimized or close to zero. The smooth reconnection also depends on the performance and accurate results of the synchronization methods. In case of UPQC microgrid-IR, reconnection is performed by the series APF. Moreover, due to the control of voltage sag/swell by the series APF, this UPQC micro grid-IR has the advantage of reconnection technique even in case of phase difference/jump (up to a some limit) between the utility voltage and at the Point of common coupling. This absolutely increases the operational flexibility of the microgrid system with high power quality.

The relation for the magnitude and phase difference Vpcc, Vsag and Vs can be obtained. The zero-crossing point of the Vsag-ref is depending upon the phase. This zero-crossing detection also indicates the point at which the instantaneous voltage difference between the utility and the PCC becomes zero.

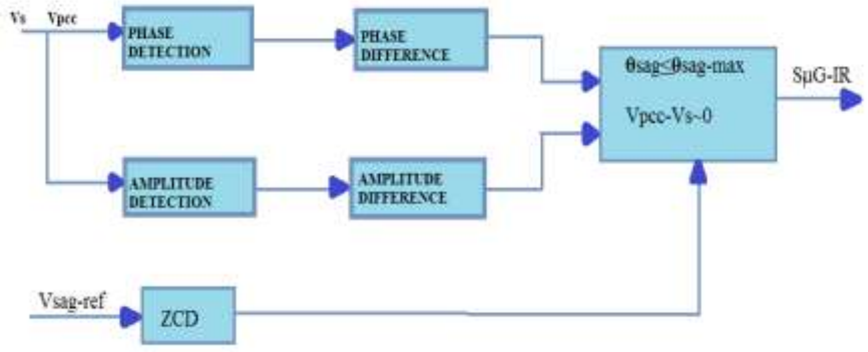

Fig.2 Synchronization and Reconnection method

The reconnection method is shown in Fig 2. Conditions for reconnection are set as; (i) assuming the phase difference between the utility grid and DG unit should be within Ɵsag-max, (ii) the instantaneous value of the two bus voltages becomes equal and (iii) these should occur at the zero crossing condition. Once the utility supply is available after a blackout, a synchronization pulse (generated in reconnection process) is enabled to start synchronization.

C. DT Algorithm

DT algorithm extracts the signal from PCC and processing the signals at a time interval. Extract the reference signal grid and compare the chosen attributes. Processing the selected attributes and sends the signals to UPQC which represents the power quality disturbances.

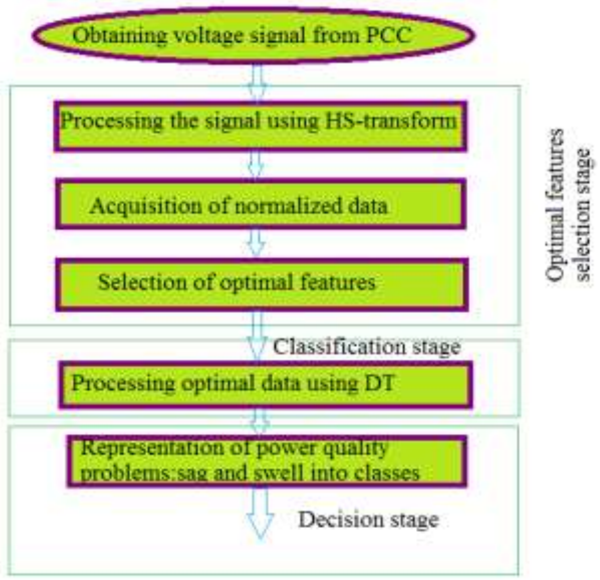

Fig. 3 Flow chart of DT algorithm

IV. Simulation Results

The simulation results of ShuntAPF, Series APF, islanding & reconnection technique for microgrid with the unified power quality conditioner using DT algorithm to evaluate the offered control stratagem. The simulation models have been established by MATLAB/SIMULINK environment. The simulation results under voltage sag and swell condition with islanding and reconnection are presented. Additionally, the simulation outcome under various load condition is also presented. The simulation results for UPQC with islanding and reconnection method is presented.

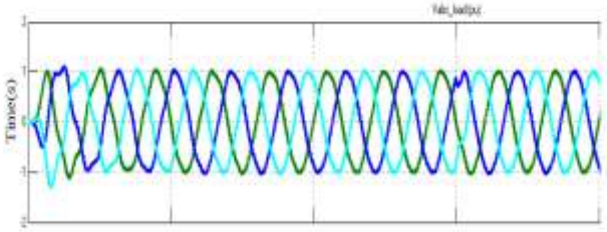

Fig.4 Simulation result for UPQC compensation

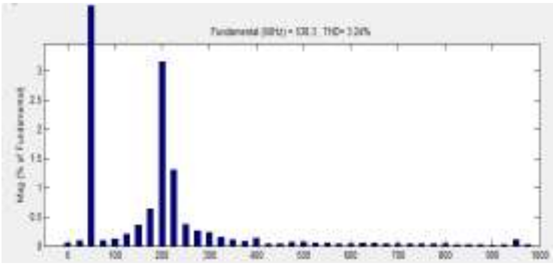

Fig.5 THD graph during 25 KW loads

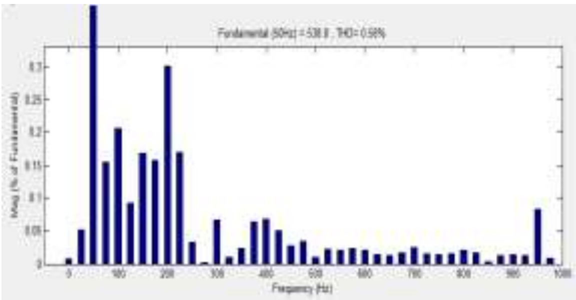

Fig.6 THD graph during 50 KW loads

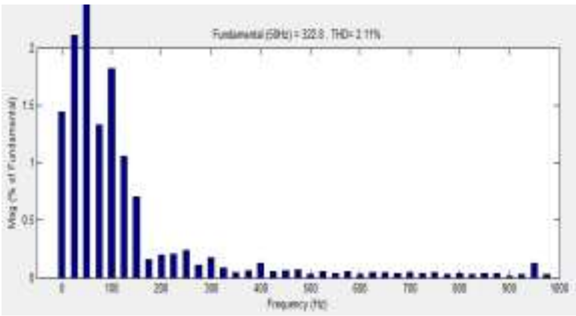

Fig.7 THD graph during 75KW loads

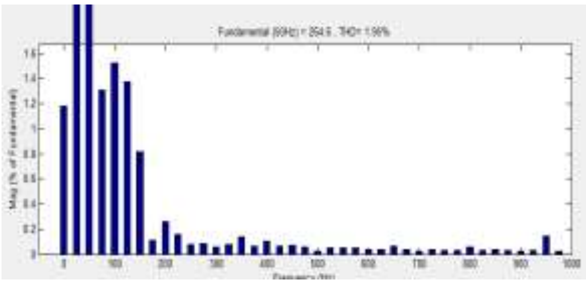

Fig.8 THD graph during 87.5KW loads

Table.1 THD Comparison of Normal System with Proposed System

S.No	Load (KW)	THD %		
		Normal System	With UPQC	With UPQC and DT
1	12.5	44.65	43.11	34.31
2	25	43.51	5.96	3.24
3	37.5	40.60	0.84	0.78
4	50	43.43	0.75	0.58
5	62.5	44.61	2.79	2.59
6	75	42.72	2.51	2.11
7	87.5	42.56	2.13	1.96

The rated generating power of micro grid is 50KW. The comparison among the normal system, with UPQC, and UPQC with DT algorithm is considered. Here UPQC with DT algorithm attains maximum performance when compared to others while considering THD values.

While operating 25% load (12.5KW), the system has high THD value. When the load increases to rated generated value of the main grid, the THD value is gradually decreases. After attaining rated load, microgrid is integrated with main grid. During that period THD value get increased. When the load is shared between the main grid and micro grid, THD value get normalized which is shown in the table.1.

V. Conclusion

A simple model of UPQC with the integration of DG based grid connected microgrid system is simulated in MATLAB/Simulink model using Decision Tree algorithm has been proposed. These results show that the proposed system can compensate the voltage disturbance at the PCC, the reactive and harmonic current compensation of the load that could inject at the PCC during the interconnected mode. Performance of the UPQC along with microgrid system is also observed in bi-directional power flow condition. During island mode, THD level is low when compared to grid connected mode.

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