International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-2, July 2019

Predictive Based Dstatcom and UPQC for Power Quality Advancement in Microgrids

Prajith Prabhakar, Antony Charles

Abstract: ***Article describes about the improvisation of power quality using Distribution static compensator and Unified power quality conditioner in microgrid. The control method used for the elimination of problems, is predictive control technique. Controller is added in the Microgrid system with three renewable sources. Filters are also added to the system to mitigate the harmonics. The two custom power devices are modeled with model predictive controller [MPC] and made to control separately the existing Microgrid system. The results are taken and compared in both Microgrid modes of operation. The output is documented using MATLAB/Simulink software. Comparison is shown differently and harmonics values are reduced.***

Keywords: Power Quality, UPQC, predictive control, Harmonics, DSTATCOM.

I. INTRODUCTION

In classical power systems, most of the power and emissions are produced by few large centralized power plants. With the help of large transmission lines produced power is transferable to large load centers that are located at maximum distance from Distributers, called Grids. The central controller continuously invigilates and supervises the power system and its equipments, to ensure the quality of power delivered to the Distributors. Global energy consumption is in rise above which reduction in fossil fuels; pave the way to the new technologies in gain. Such drastic increase of energy consumption can be eliminated potentially with the incorporation of non- conventional energy sources and distributed generation sources. [1] .

An efficient arrangement to connect all the distributed energy resources consisting of renewable sources is the Microgrid. Microgrid Structure consists of low voltage distributed system which have lot of disturbances, after the nonlinear loads are been connected [3]. Non-linear loads like arc welders etc will increase the flow of reactive power to them by generating harmonics. In the case of faults, Microgrids has to work autonomously with the help of internally generated reference power to reduce the harmonics or reduction in reactive power to the loads. The mitigation of all power quality issues will be mitigated by the use of either passive filters or Compensation devices. Compensation devices mentioned won't have the best compatibility with the Microgrid system. The parallel connected inverters are the main sources of harmonics in Microgrids. Presently, most inverters used in Microgrid endorse voltage source Inverter topology to regulate the current given to the grid. The high-accuracy control of an instantaneous current, peak-current protection, overload rejection, and very good dynamics are the advantages of current controlled inverter arrangement. In order to have good capability of rejection in harmonics, the performance of VSI can be applied in order to meet the requirements [9].

Power quality field consists of several researches going on. In the solution of compensation of real and reactive power with elimination of harmonics, there are various other methods in use in Distribution system. [5]. This paper discuss about the usage of static compensator and power quality conditioner using predictive technique for the existing Microgrid system. The algorithm for control chosen for remedy to the power quality issues seen in Microgrid is predictive control. Compensated real and reactive power are been injected in the voltage and current format into the point of common in the proposed Microgrid by MPC based DSTACOM and UPQC. Both the results are compared in Simulink platform. In the advancement of process control MPC plays a major role by considering the future time slots. According to that consideration controller has the merit to anticipate the after time action and work according to that particular action. The adjustment in reliable variables of the modeled system will be forecasted by the controller itself which causes change in self- contained variables.

II. DESIGNED SYSTEM

The analysis of power issues are done in the particular section along with the Microgrid Model. The symbolic representation of Microgrid system is shown in the Figure 2.1.

Revised Manuscript Received on 30 July 2019.

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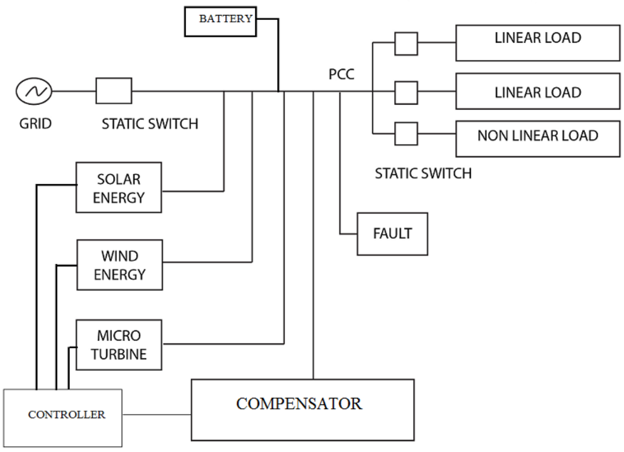

Fig.2.1. Microgrid Design.

In the Microgrid System, solar block, Wind block and Microturbine block was modeled in two modes and also in transient analysis mode by MPC control method successfully. The existing Microgrid was compensated with DSTACOM and conditioner and is then connected in PCC through static switch with linear and non-linear loads Microgrid works autonomously in Islanded mode with internally generated values by the Microgrid central controller. Incandescent lamps, Heaters may be the linear and the Non- linear loads. Fault detection by Microgrid central controller gives signal to the Static switch to open in Islanded mode. Predictive algorithm in each and every block makes the compensation possible in the Microgrid where even communication is also not possible with the main grid. Here DSTATCOM and UPQC are used as compensating devices to mitigate the harmonics and inject compensated currents into common point (PCC). The power flow conditioner will supply compensated currents through two on either side transformers to the PCC.

Most widely used control techniques for new technologies in the field of Power system. A reasonably accurate and precise controller model will be formulated for the present current system. All the possible consequences of the current and future input moves are forecasted online leading to optimal design. Formulation of algorithm controls by four tuning parameters. They are weight matrix, the output weight matrix the prediction horizon and the control horizon. After the implementation of first control action, model state will be forecasted again and get the new calculations by repeated action. This yields the new control and manipulated path for formulation. By accepting the changes in the control signal head MPC initiates the control action. This model works in two modes of operation

1) Grid connected Mode using DSTATCOM:

In this mode, through a static switch Microgrid system is associated with the main grid network. Grid provides the references to the controller for the purpose of compensation. The Predictive technique controls and compensates the Microgrid with additional reactive power component if needed. The Diagram shown below explains how Microgrid connected with Grid using DSTSATCOM is given in figure below.

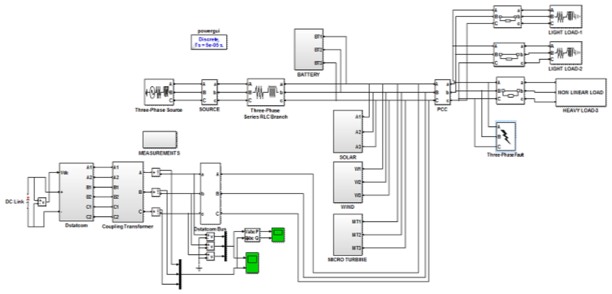

Fig. 2.2. Grid Integrated Mode

The distribution static compensator along with the predictive control will eliminate the harmonics formed in the Microgrid system. The dynamic matrix model has the parameters in the matrix model so that complex systems like microgrid can be controlled.

2) Islanded Mode using DSTATCOM

Due to planned or unplanned events that occur in power system cause the disconnection of Microgrid would take place immediately. Three DGs are connected at the common point and modeled using MPC controller. Static compensator via transformer will provide the additional currents and voltages due to the signal given from MPC based central controller. Local modification in the generation profile of the DGs and the battery is too possible to meet the requirements of the loads. Microgrid central controller generates the references for the smooth function of Microgrid. In turn eliminates the power quality issues also. The Simulink diagramed representation of Microgrid system in isolated mode with DSTATCOM is shown in Fig. 2.3.

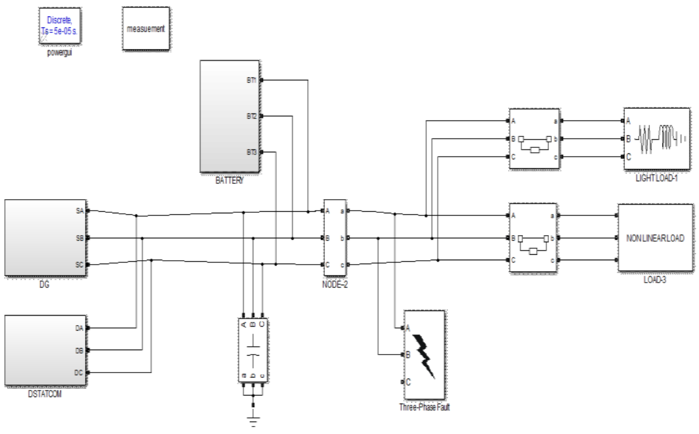

Fig.2.3. Islanded mode

Full compensation is not possible in isolated mode with the non-linear loads in the Microgrid system. The quality of power delivered to the loads should be dominant by using the present network. A modification in the existing system was recommended by the addition of compensating devices. For the smooth function of Microgrid in this mode, CPD is needed at the distribution side. The integration of the power devices and also the non-linear loads will make pavement of harmonics to the loads and DGs.

Retrieval Number: B1069078219/19©BEIESP
DOI: 10.35940/ijrte.B1069.078219
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Comparison on two CPDs has been present in this paper. With DSTATCOM microgrid was seen in previous section. Now the same microgrid system is compensated with the help of UPQC. The process is occurred in 2 different modes abruptly.

1. Grid Integrated Mode Using Upqc

The existing system was added with series and shunt compensation Conditioner at the common point. UPQC was added to PCC as both series and shunt. The device will act the as both DVR and DSTATCOM to the existing Microgrid system [10].

In the grid compact mode the controller will have the references from the grid and these will act as the reference to the UPQC model and model predictive controller.

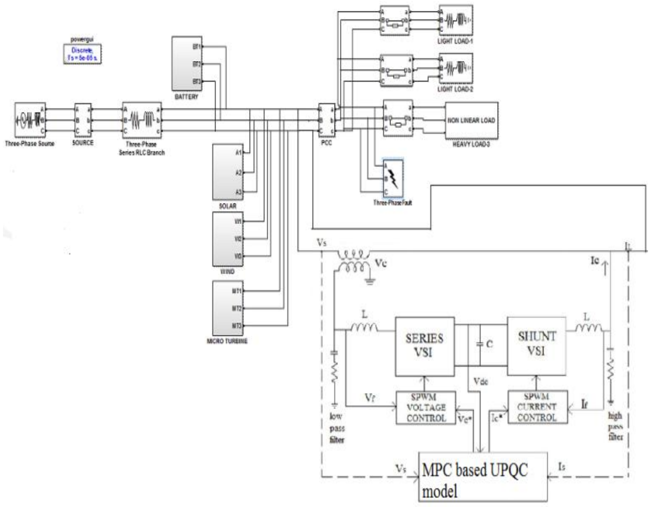

Fig.2.4. UPQC in Grid connected Mode

In the above diagram, static compensator is replaced by power quality conditioner to check the compactness of the device with Microgrid. It is the combination of series as well as shunt voltage source inverter, which in turn connected with the PCC using series transformer and the shunt transformer with a common DC coupling. UPQC consists of two VSI based IGBTs whose gate pulses are controlled by the model predictive controller.

Shunt comparator connected to PCC supports the load ad supplies harmonics currents. Series converters mitigate the distortion in the input current and unity current values shall be improvised for the loads. The pulses to the both converters are supplied from the help of MPC and the dynamic matrix control method. This improves the quality of power in Grid integrated operation mode by eliminating the harmonics and maintains the load end voltage in presence of reduction in supply. Voltage injection was also improved to manage end load voltage.

Predictive based DSTATCOM and UPQC along with the battery if needed, interject compensated currents and voltages to the common point. Simulink MPC controller is given in figure 2.5.

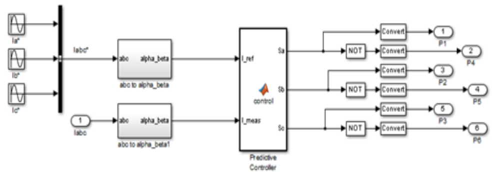

Fig.2.5. Model Predictive Controller

MPC produces the references and which are converted to dc version and produced to along with sensed currents or voltages to predictive simulation tool box. Uncompensated signals are sensed for the each block output and also fed to Simulink tool box. Compensated output signals will be provided to the PCC from every modeled distributed resources with predictive technique control algorithm. Modeled Solar with MPC is shown in the Figure 2.6.

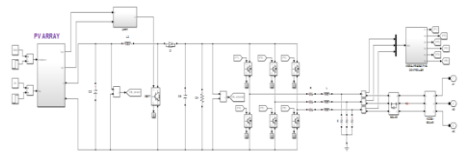

Fig.2.6 Solar Model with MPC

Model consists of photo voltaic array panel that senses the sunlight and produces electric current which is fed to IGBT thyrsitor. This arrangement is implemented in both modes of operation with two compensators. The pulses to the thyrsitor are given from the Predictive controller.

2. Islanded Mode using UPQC

The same MPC based UPQC was implemented in the Microgrid system with three renewable energy sources. The grid will be disconnected at some point of time due to the internal or external faults. Microgrid has to act autonomously with the attenuated and non- attenuated loads. In the contraption of UPQC in islanded mode, incorporated model was modified and UPQC was included. The UPQC based microgrid model in islanded mode is shown in figure 2.7.

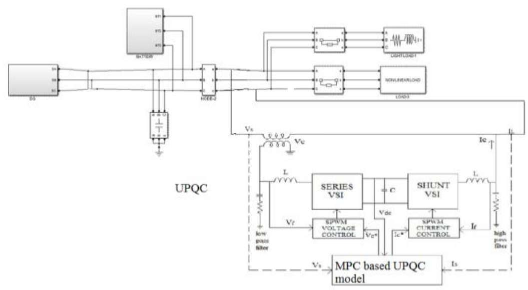

Fig.2.7. UPQC in Islanded mode

Incorporated model is implemented in this mode of operation. The grid is been disconnected from the system and Microgrid will be works autonomously with the help of predictive technique reference generator. These reference values will be used for the generation of pulses and given to IGBTs in the UPQC. With the help of passive filters, output at the PCC can be filtered and smoothen to a larger extent.

III. RESULTS & DISCUSSIONS

The test model shown in the Figures shown in the section 2 which contains three renewable energy resources along with microhydel turbine output are also modeled with predictive algorithm. Varying output models like solar and wind will have their own prediction model along with non-linear MPC will be compensating the power output. The ratings are 5 kW and 10 kW active and reactive powers vary with time. Two light loads of 50 kW each and one non-linear load of 20 kW and 9 kVAR and 12 kVAR respectively. Grid value is 2500 x10^6 VA and 50 Hz frequency.

The system was tested using Simulink in the two operation modes with both the compensators.

1) Grid Connected mode:

The progression of simulation is follows. The value of load 1was reduced from 50 kW and 20 kW to 25 kW and 5 kW. The static switch was opened at 0.2 s with the signal from the controller to check the stability variation, so that the Microgrid was isolated from the main grid. Active & Reactive power output graphs are shown at the Grid and load side in the figure 3.1 & 3.2. This sequence happens to be common for both compensators. The output and the compensating methods were different in two cases. The harmonics were compensated and mitigated in both modes of operation. But reactive power compensation was efficient in MPC based UPQC grid connected mode. The simulation graphs shown in the figures 3.1 & 3.2 are of the MPC based DSTATCOM. On grid side reactive and active power was compensated with the help of Dynamic matrix control of predictive control technique. The parameters are so chosen that it had already had the compatibility with test microgrid system. The THD value is below 4% in grid connected mode of operation.

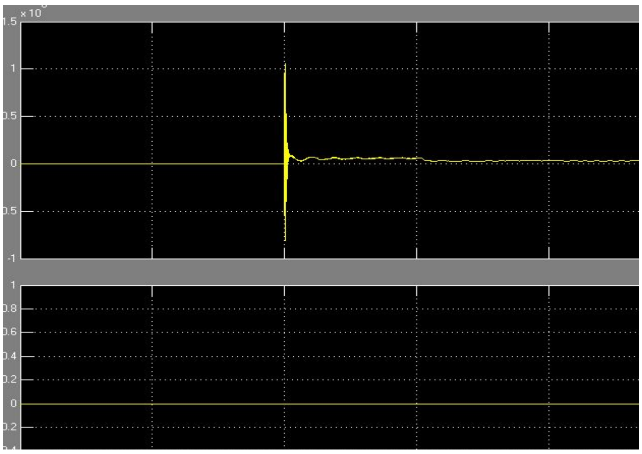

Fig 3.1.Grid Side Active & Reactive power

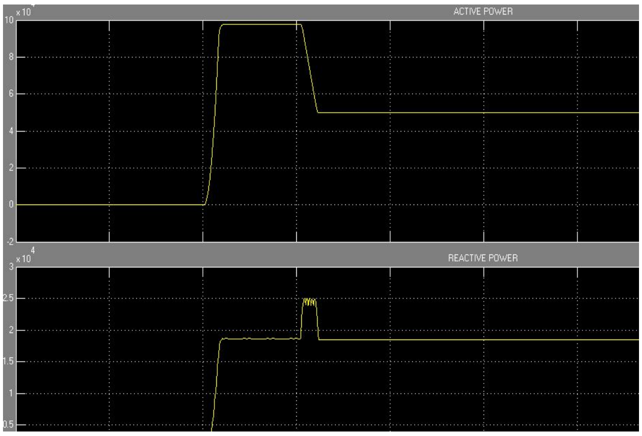

Fig .3.2. Load side Active & Reactive power

It is clear from the above mentioned graphs, that every loads were incorporated to the grid that makes the real power as 95kW and reaction power as 190 kVAR with a small spike. The same microgrid system was tested with MPC based UPQC in grid connected mode of operation. This variation can be seen in the graphs shown below in Fig.3.3 & 3.4.

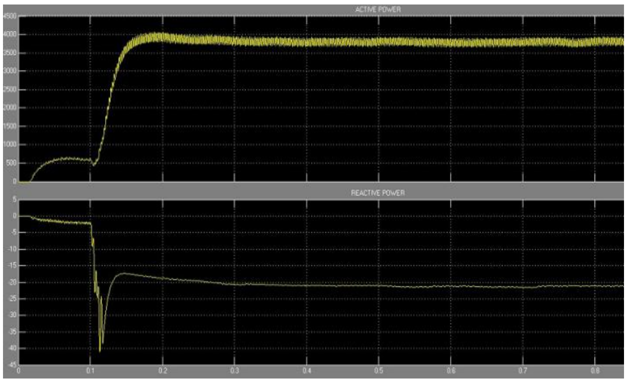

Fig. 3.3. Grid side Active & reactive power UPQC

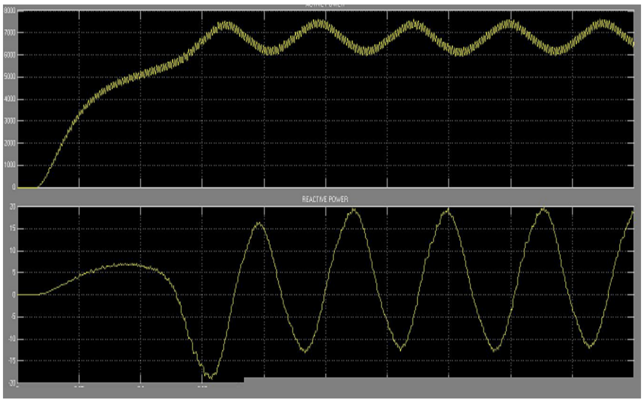

Fig.3.4. UPQC load side Active &Reactive Power

The battery is also incorporated in the compensation process in UPQC grid connected mode. By the compensating procedure done by UPQC with MPC, harmonic current flowing through the load and demand for reactive power in load has been decompensate completely along with the constant dc link voltage.

2) Islanded Mode:

The Microgrid central controller sends signals to the static switch to open the on unplanned conditional events. Immediately the main grid is detached from the system. Load been diverse for different values. The modeled inverters with MPC work autonomously. The DG output will be compensated with the help of central controller, if there is any decrease in output of energy resources. Microgrid Isolated mode is shown in Fig. 2.3.

Loads are connected to Microgrid; to be compensated by the MPC based DSTATCOM at the PCC. From the figure 3.5.a, DSTATCOM compensates the real and reactive power in the Isolated mode up to 0.2s.The value of active and reactive power are both negative. Figure 4.5 shows the real and reactive power at the load side.

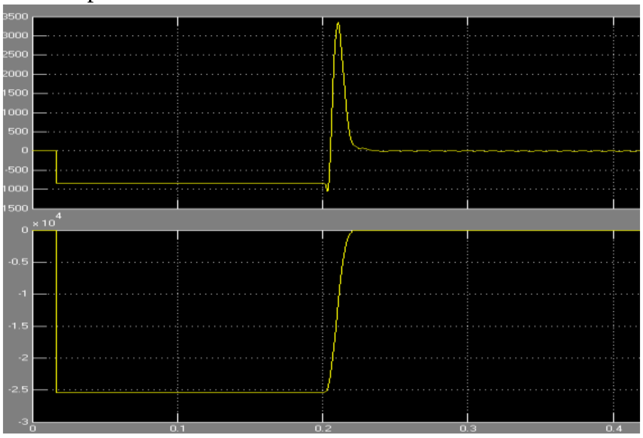

Fig.3.5.a.DSTATCOM output in Islanded Mode

On connection with non-linear load, we can view the variations in voltage. Variation is given in figure 3.5.b.

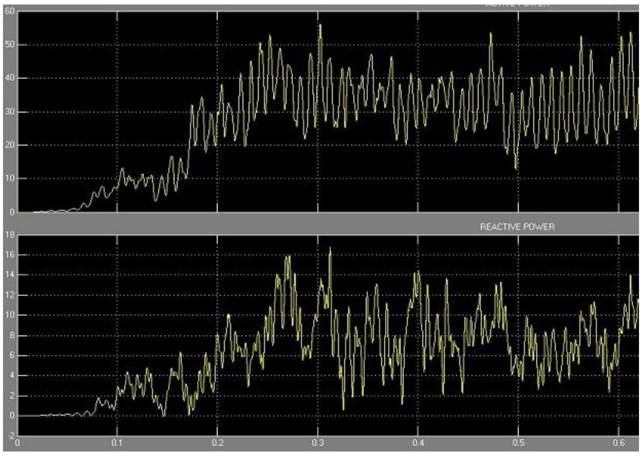

Fig.3.5.b. Real and reactive value at load side

Presence in second order harmonics were detected. Every DG's are connected to a single model as the non-linear MPC and dynamic control method as shown in Figure 3.6. Improvement of values can be seen which increases the system stability.

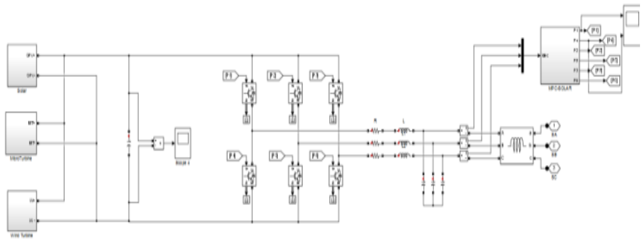

Fig.3.6.Incorparated view of DG's

The incorporated model has all the DGs into one with NMPC method and the compensation is possible at PCC with both the compensators. Compensation of reactive power is completely done in this mode with distribution static compensator. Graphs show the negative power due to the presence of lightning ballasts and several loads.

In islanded mode of operation like similar structure is used for the compensation in Microgrid system. The incorporated model is used in the case of UPQC too. The output is shown below.

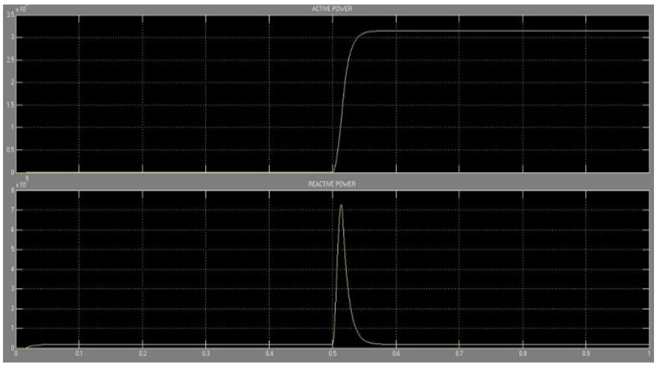

Fig. 3.7. Load side Real and reactive power

IV. COMPARISON

Graphs convey that the complete compensation is possible with the help of both compensation devices. But the case with total harmonic distortion the UPQC is having the lowest value of 3.5% and that of DSTATCOM is 4.9 %. But the implementation is so much easier with distribution static compensator than conditioner in the controller part in Microgrid system. In Grid integrated version, all the compensation devices work properly with the existing reference currents from the grid to the Microgrid central controller. In Islanded mode, an incorporated model was proposed on both compensators with the presence of non-linear load. Predictive technique uses non-linear predictive control from linear control system to recoup the harmonics and reactive power.

V. CONCLUSION

Predictive based Distribution static compensator and active conditioner was implemented with a Microgrid system.

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DOI: 10.35940/ijrte.B1069.078219
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The authenticity of Microgrid system and its complete compensation were invigilated with simulation results in software. Predictive controller implementation and mitigation of the issues in power qualitywere studied and analyzed by Microgrid design system. Both the compensators were integrated into the existing system and results compared in all modes of operation. DG compensates the unbalanced loads and shares with pre specified ration with the Grid. In isolated mode, another efficient incorporated model was proposed to mitigate the harmonics and reactive power compensation. According to the future analysis and advantage variations of voltage and frequency the linearization of non-linear predictive model was suggested for the smooth functioning of Microgrid. Fault analysis with MPC based UPQC has to done in the future development and satisfactory results has to be produced for all types of faults.

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