International Journal of Engineering & Technology, 7 (3) (2018) 996-999

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i3.11182
Research paper

Power quality enhancement in micro grids by employing MPC-EKF

N Narender Reddy[1]*, O Chandrasheker[2], A Srujana[3]

[1]*Research scholar KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India –522502*
[2]*Professor & HOD in EEE Dept and KoneruLakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India –522502*
[3]*Professor in EEE Dept Sri Venkateswara Engineering College, Suryapet, Telangana State, India-508233*
**Corresponding author E-mail:nnr_rin@yahoo.co.in*

Abstract

This paper proposesdesign of a novel multi-level Control system based on Model Predictive Control Algorithm with Extended Kalman Filter (MPC-EKF) to enhance the power quality. The system utilized here implements few controllers based on MPC-EKF front end control, Top down control system and Bottom up control system to monitor periodic signals for fast sampling .TheMPC control divides the said problem into steady-state and transient sub problems individually and improves the response of the individual states .EKF traces the harmonics in the system improves power quality. The top down control system is responsible to improve the separated transient response and the bottom up control system is responsible to track the steady state error. Thus the proposed method is provided with the capability to enhance the quality of power and reliable performance of the microgrid by tracing and removing the harmonics in the distribution system, thereby decreasing the computational time. Our proposed method can be implemented on the MATLAB/SIMULINK plat form to validate the results.

Keywords:*Kalman Filter(KF); Extended Kalman Filter(EKF); Particle Swarm Optimization;Microgrid and Model Predictive Control Algorithm.*

1. Introduction

Increase demand for power have let researches explore various sources of power generation, various methodologies need to be adopt to reduce consumption. Lot of investigation also carried out related to network interconnection, arises problems and their mitigation techniques. One practice which is adopted since the recent past is to connect microgrids to the distribution network to match the power demand there by enhancing supply capacity of the distribution network.

The point of interconnection of the distribution network with the microgrid is termed as PCC. These interconnections have affected the performance of the distribution network by causing fluctuations in grid voltage and frequency. It has also resulted in injection of harmonics in supply side voltage and load side current[1]. Such kind of power quality issues were addressed by introducing conventional power conditioning equipments like Hybrid Active Power Filters [2], Dynamic Voltage Restorers [3] and UPQC [4]. By connecting them locally at the individual loads, which resulted in large run time. An approach implemented to reduce the run time was to bifurcate the problem in to two sub problems as steady state and transient state, solving them simultaneously.

Due to the ability Model Predictive Control algorithm to take care such kind of constraints [5], it is encouraging to adopt MPC for solving steady state and transient state sub problems on the same time scale. Injected harmonics in the load current and grid voltage can be reduced by employing frequency dividing method, selective harmonic elimination [6] etc. However the elimination of harmonics by those methods enhances the power quality to some extent only. Therefore a novel particle swarm optimization technique with selective harmonic elimination method is implemented in the proposed paper.

2. System description

The block diagram of the micro grid in the proposed paper is shown in Fig. 1.The proposed system is a two feeder radial distributed network. Feeder1 is connected to a distributed generation (DG) unit comprising of a micro generator like solar micro grid (SMG) and wind micro grid (WMG), these two grids are connecting to the feeders via static converters. Feeder2 is connected on the load side. At PCC these two feeders are connecting to main grid along with a model predictive controller with extended kalman filter in order to enhance the power quality.

The proposed system can be put in to operation in two different ways i.e. PQ compensation mode (mode 1) and the islanding mode (mode 2). During mode1, the micro grid is connected to the distribution grid at the PCC. In this mode, SMG and WMG are controlled to generate real power locally and back up voltage for loads-1, load–2 and hence scale down the burden on the amount of power conveyed by the main grid. The model predictive controller with extended kalman filter functions to filter out developed harmonics in the variable currents drawn at different loadings which are connected to SMG and WMG. This inhibits propagation of harmonics to the remaining loads connected to the PCC. Switching in and out of connected load and steep variations in the load demand may also effect in extensive changes in the grid voltage as well as in frequency. Therefore the model predictive controller is also embedded with the facility to handle such fluctuations in grid voltage as well as in frequency.

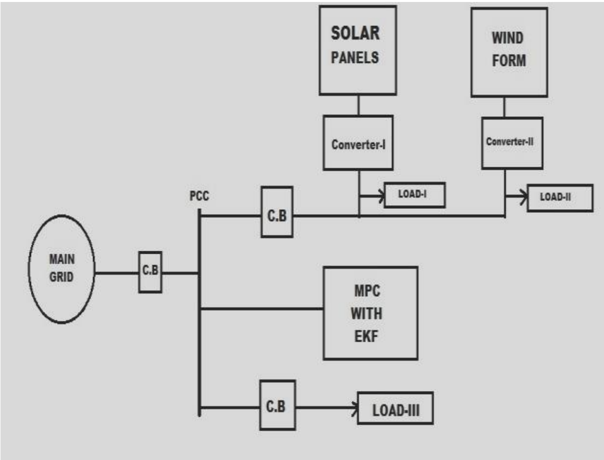

Fig. 1: Proposed micro Grid Schematic Diagram.

When there occurs a fault on the grid connected network, the CB disconnects micro grid from the distribution network. On those status the SMG and WMG are the only available sources of power supplyin the distribution network to direct the loads. If the maximum load demand exceeds the maximum power that can be trapped from the micro generators then the controller switches the distributed network to operate in the emergency mode.

3. Islanding detection methods

Various techniques have been developed to detect islanding as explained in[7]. These techniques can be broadly classified into central (remote) and local methods as illustrated in Fig. 2.

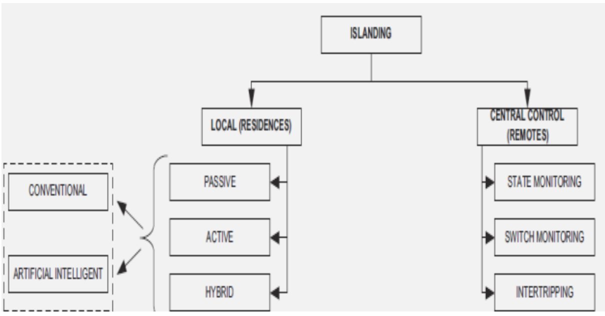

Fig. 2: Classification of Islanding Detection Techniques.

The hybrid technique is a combination of the active and passive techniques, The active technique is applied only if islanding is detected based on the passive technique. Comparison of various active islanding detection techniques are explained in table-1.

Table 1: Comparison of Active Islanding Detection Technique

Sno	Method	Implementation and speed	Weakness	NDZ
1	Impedance measurement	Simple and high speed		Large for high Q load
2	SMS	moderate and slow	Ineffective under certain load	Large for high Q load
3	AFD	Easy and medium		Large for high Q load
4	SFS	Difficult and relatively fast	Problem in PQ, stability	Exist for high Q load
5	SVS	Medium and fast	Increased harmonic distortion	Very less

Notable variations can be seen with respect to the 5th harmonic signatures i.e current and voltage at the PCC during the grid-connected and autonomous modes of operation because of variations in the network inter connection. The output waveform of the 5th harmonic can be modeled as:

$$V(t) = \sum_{n=1}^{5} a_n \sin n\alpha_n \tag{1}$$

Where α_n is the switching angles. The amplitude of the nth harmonic in terms of p.uis given by:

$$a_n = -\frac{4}{n\prod}\sum_{k=1}^{m}(-1)^k \cos n\alpha_k \tag{2}$$

In SHE a_1 is assigned the desired value for fundamental component and other coefficients corresponding to the harmonics to be eliminated are equated to zero. This can be expressed as:

$$a_n = -\frac{4}{n\prod}\sum_{k=1}^{m}(-1)^k \cos n\alpha_k = 0, \quad for\ n \neq 1 \tag{3}$$

The voltage magnitude of the 5th harmonics present at switch 2 when switch 1 is closed can be calculated as:

$$V_{PCC-EKF}^{5th} = V_{EKF}^{5th} \cdot \frac{Z_l^{5th}}{Z_G^{5ht} + Z_l^{5th}} + I_{MG}^{5th} . Z_G^{5th} \parallel Z_L^{5th} \tag{4}$$

Where Z_l^{5th} is the harmonic impedance of the load and Z_G^{5th} is the harmonic impedance of the network. The voltage magnitude of the 5th harmonics present at switch 2 when switch 1 is open can be calculated as:

$$V_{PCC-I}^{5th} = I_{MG}^{5th} . Z_l^{5th} \tag{5}$$

In the proposed research work each particle in the swarm is said to be the switching angles of the harmonics. With the aim of sinking the harmonics produced in the system the fitness function can be formulated as:

$$F(x) = \min[THD] \tag{6}$$

Where,

$$THD = \left[\frac{1}{a_1^2}\sum_{n=5}^{\infty}(a_n / n)^2\right]^{1/2} \qquad n = 6i \pm 1 (i = 1,2,3,...)$$

4. Proposed control methodology

The proposed model predictive control algorithm is a wing of developed MPC algorithm in [8], specifically drafted for fast-sampling systems to monitor periodic signals. This algorithm bifurcates the MPC optimization into two sub problems that is steady-state and transient sub problems which are workout simultaneously by varying the time scale without overlap there by shorting the run time. The MPC control methodology also identifies the harmonics present in the system with the help of EKF to improve the quality of power.

The state space model of the microgrid after time discretization is given by:

$$x^+ = Ax + B_1 w + B_2 u \tag{7}$$

$$y = Cx + D_1 w + D_2 u \tag{8}$$

Where + represents the time shift operator and w is the periodic exogenous signal which is modelled as:

$$w = C_w \xi \tag{9}$$

$$\xi^\bullet = \overline{A}_\xi (f_g, f_{mg})\xi \tag{10}$$

The reference current and voltage of the microgrid should be tracked which is given by:

$$d = [dv_{mg} \quad di_g]^T = C_d \xi \tag{11}$$

The exogenous state ξ, can be identified with KF from the signal w being measured and the reference d being specified. The distribution grid frequency f_g may be subjected to slight but unknown variations, which needs to be estimated from the measurement of v_g. To achieve this, an augmented model is employed by:

$$\xi^+ = A_\xi(f_g, f_{mg})\xi = \exp[\bar{A}_\xi(f_g, f_{mg})T_s]\xi \tag{12}$$

$$f_g^+ = f_g \tag{13}$$

$$w = C_w \xi \tag{14}$$

$$d = C_d \xi \tag{15}$$

As the augmented model is nonlinear an EKF is proposed to estimate ξ and identify f_g simultaneously. The complete configuration of the proposed model predictive controller with KF and EKF is shown in Fig. 3.

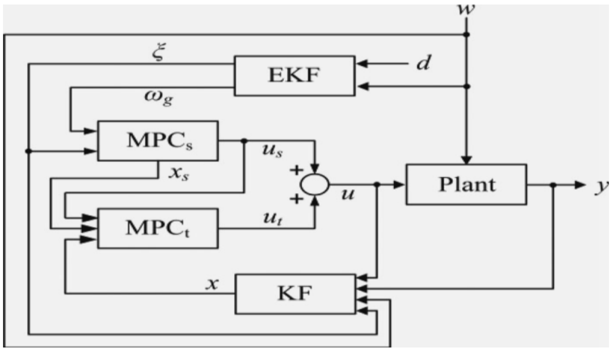

Fig. 3: Model Predictive Controller with KF and EKF.

A novel Particle Swarm Optimization with Selective Harmonic Elimination (PSO-SHE) method can be employed for the effective elimination of harmonics identified by the filter. Also from the knowledge of the magnitude variation of 5^{th} harmonics islanding mode of microgrids can be detected.

5. Results and comparison

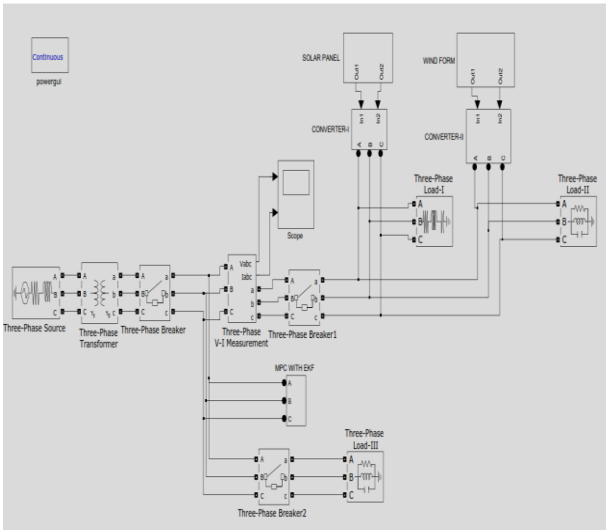

Fig. 4: Simulink Model of the Proposed System.

The proposed system's simulink model as shown in figure5, simulated in MATLAB and the retrieved results are discussed in this section. The EKF in the proposed MPC controller identifies the harmonics generated by the output power delivered to the load. The total harmonic distortion generated by the proposed system in terms of current and voltage is shown in figure 5.In order to increase the power quality and preserve the stability we employed a particle swarm optimization based selective harmonic elimination technique which attenuates the harmonics observed by the EKF. The optimized harmonic output resulted by PSO-SHE is shown in fig 6.

The THD value optimized by the proposed PSO-SHE in comparison with some conventional techniques is given in table 2.

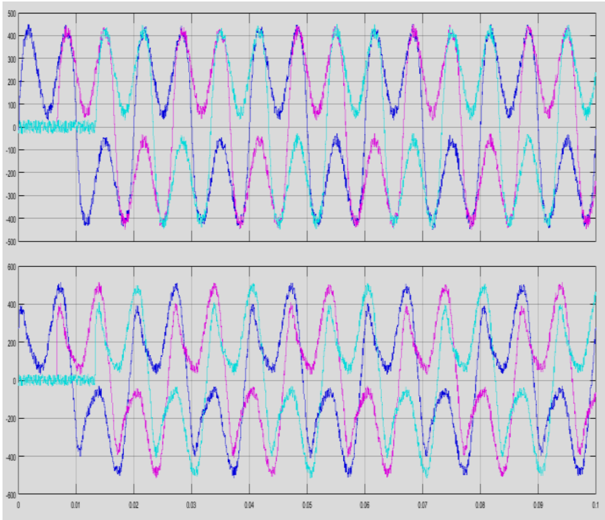

Fig. 5:THD Resulted from the EKF.

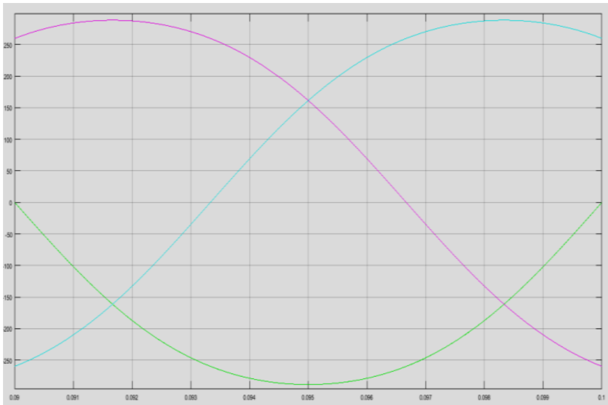

Fig. 6: Optimized Harmonic Output with PSO-SHE.

Table 2: Optimized THD value of PSO-SHE in Comparison with Existing Methods

THD(%)	SHE	PSO-SHE
THD in terms of voltage	5.42	4.987
THD in terms of current	6.31	5.99

The graphical representation of optimized THD value comparison of harmonic elimination technique in terms of current and voltage is shown in fig 7. From figure8 it is evident that the THD values resulted from the proposed harmonic elimination technique is significantly smaller than the existing technique in terms of both voltage and current.

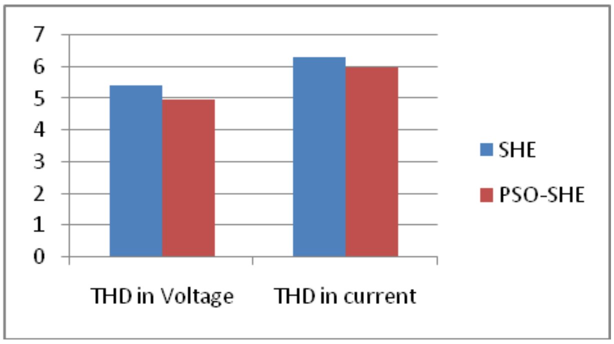

Fig. 7: THD Comparison.

6. Conclusion

In this paper, a novel multi-level Control system based on Model Predictive Control Algorithm with Extended Kalman Filter (MPC-EKF) has proposed to strengthen the power quality. The MPC control methodology bifurcates the control problem into steady-state and transient sub problems separately and boost upthe transient and steady state responses and also identify the harmonics present in the system with the help of EKF. By employing Particle swarm optimized with selective harmonic elimination technique THD in terms of voltage as well as in current is significantly reduced and improves the quality of power.

References

[1] Tan, K. T., et al. "A flexible AC distribution system device for a microgrid "IEEE Transactions on Energy Conversion, Vol. 28, No. 3, pp. 601-610, 2013.https://doi.org/10.1109/TEC.2013.2260162.
[2] An Luo, ZhikangShuai, Wenji Zhu, Ruixiang Fan, and Chunming-Tu"Development of Hybrid Active Power Filter Based on the Adaptive Fuzzy Dividing Frequency-Control Method" IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 24, NO. 1, pp.424-432,JANUARY 2009
[3] A. Gosh, A. K. Jindal, and A. Joshi, "Design of a capacitor-supported dynamic voltage restorer (DVR) for unbalanced and distorted loads," IEEE Trans. Power Del., vol. 19, no. 1, pp. 405–413, Jan. 2004.https://doi.org/10.1109/TPWRD.2003.820198.
[4] K. H. Kwan, Y. C. Chu, and P. L. So, "Model-based H∞ control of a unified power quality conditioner," IEEE Trans. Ind. Electron., vol. 56,
[5] J. M. Maciejowski, Predictive Control with Constraints, Prentice-Hall, New Jersey, NY, USA, 2002
[6] DavoodYazdani; AlirezaBakhshai; GÉzaJoos; Mohsen Mojiri."A Real-Time Three-Phase Selective-Harmonic-Extraction Approach for Grid-Connected Converters"IEEE Transactions on Industrial Electronics, Volume 56, Issue 10, pp.4097 - 4106, 2009.
[7] Khamis, Aziah, et al. "A review of islanding detection techniques for renewable distributed generation systems." Renewable and sustainable energy reviews, Vol.28, pp. 483-493, 2013.https://doi.org/10.1016/j.rser.2013.08.025.
[8] Y. C. Chu and M. Z. Q. Chen, "Efficient model predictive algorithms for tracking of periodic signals," J. Control Sci. Eng., vol. 2012, pp. 1–13, 2012.https://doi.org/10.1155/2012/729748.