INTERRELATED CONTROL OF DISTRIBUTED GENERATORS AND COMPENSATOR IN A MICRO GRID

V.TAMILSELVAN[1], S.SIVA SUBRAMANIAN[2], V. DINESH KUMAR[3], P. HOSANNA PRINCYE[4]
[1&2]Professor,Karpagam College of Engineering, Coimbatore, Tamilnadu
[3]Associate Professor, Kumaraguru College of Technology, Coimbatore, Tamilnadu.
[4]Associate Professor, SEA college of Engineering and Technology, Bangalore, Karnataka

Abstract: ***The main objective of this paper is to enhance the interrelation between Distribution Static Compensator (DSTATCOM) & Distributed Generators (DGs) in the microgrid. If the more number of Distributed Generators (DG)s are connected in parallel in order to fulfill the supply demand, a problem in mismatch of reactive power arises. So, the main purpose of the paper is to increase the PQ by inserting a DSTATCOM with modified control techniques. In this paper, the reactive power compensation (RPC) control strategy is based on Voltage drop and power flow. The simulations provided with DSTATCOM gives the best output as compared to the conventional control methods.***

Index Terms: DSTATCOM, Voltage Source Inverter (VSI), Microgrid, Distributed Generators (DGs), Reactive Power

I.INTRODUCTION

The world is looking forward about green power as conventional fuels are exhausted day-by-day. Power Converters is part&parcel in the present scenario to convert power from DC to AC due to its many issues in power quality challenges being faced in the micro grid. These problems can be resolved with the eco-friendly power resources [1]. Installment of DGs to improve a performance of microgrid for control agencies in generation of power. The concept of Microgrid [2] was proposed to implement various natural renewable energy sources into distribution systems in a smart way. Distributed Generators (DGs) are connected in parallel to provide major amount of power with more reliability & efficiently [3]. For instance, when two DG's are connected in shunt, they do not share reactive&active powers uniformly. So, few strategies have implemented such as compensators to get stability&uniformity. The main possibility is to control the DG's&compensating devices. In this grid, the power electronic converters will control the PQ challenges. In the present world, various reactive loads such as pumps, fans, motors etc require more lagging power factor. DSTATCOM [4] provides Reactive Power as needed by load & the source current provides unity power factor.

Distribution Static Compensator (DSTATCOM) is quick&fast operated controller & gives voltage support & PQ improvement & in addition to these, it provides the traverse from capacity transients to microgrid [5].

In any case, Active & Reactive powers in a low-voltage system plays critical path of voltage. DSTATCOM is made either bus voltage or line current compensation [6-10]. In microgrid, distributed generators (DGs) work along with control of voltage to get RPC with distributed generators [11]. The main problem of this paper is to made reactive power compensation with DG's&DSTATCOM[12-14]. This proposed technique make sure for rapid RPC with the regulation of voltage limit [15]. The results reveals that reactive power compensation can be achieved with the proposed control strategy.

II. MICROGRID CONFIGURATION

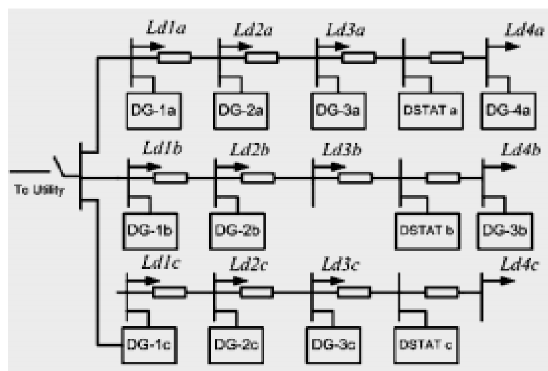


Figure 1: Structure of Microgrid

The figure indicates microgrid structure with one DSTATCOM, 4 Distributed Generators (DGs) & 3 feeder segments in phase-A, 3 DGs & 1 DSTATCOM in phase-C, 1 DSTATCOM & 3 DGs in phase-B. Four loads are connected in each phase. The specifications of simulations & modeling are tabulated given below:

Table-I Parameters of Grid

Grid	
Voltage	400 V L-L RMS
Frequency	50 Hz
Line Impedance	R=0.1Ω, L=0.001 H
Load Type	
Resistive	Singe-Phase Resistive Load

Table-II Parameters of Controller & Converter

No. of Converter in Phase A	4		
No. of Converter in Phase B	3		
No. of Converter in Phase C	3		
Rated Output power of DGs	Phase A	Phase B	Phase C
DG-1	1.5kW	4.0kW	5.0kW
DG-2	4.0kW	4.0kW	4.0kW
DG-3	5.0kW	3.0kW	5.0kW
DG-4	5.0kW	xx	xx
Converter Structure	Single-Phase H-Bridge Inverter		
Converter Loss	R=0.1Ω per phase		
Transformer	0.400/0.230 kV, 0.5 MVA, L_{tr}= 4.4 mH		
LC Filter	L_f=49.8 mH, C_f=50μF		

IV. PROPOSED CONTROL OF POWER FLOW OF DSTATCOM& DG

The interrelated between DGs & DSTATCOM (Distribution Static Synchronous Compensator) is illustrated in the present section. The basic objective of Reactive Power Compensation (RPC) is based on voltage variation & power flow in line. In order to obtain regulation of voltage, it considers the power flow in the control of DSTATCOM (Distribution Static Synchronous Compensator Control)

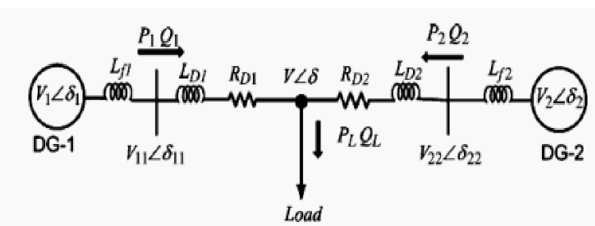


Fig 2. Single Line Diagram of Two Machine System

Basically two machines are given as sample shown in figure 2 to understand the relations between Reactive Power (RP) & active power. Eventually Multi-Machine system is explained for RPC. The samples are explained to acquaintance the concept of DSTATCOM & DGs control.

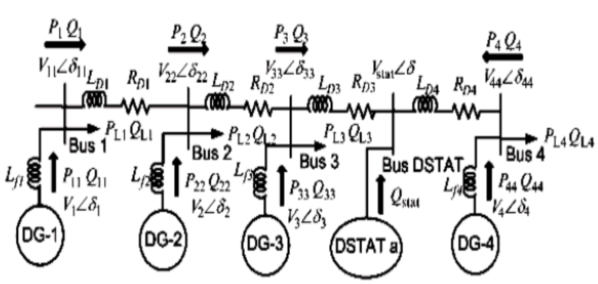


Figure.3 Indicates about Multi machine system

The current & reference voltage generated to provide the reactive power compensation is expressed in [17]. Increase in Reactive Power (RP) demands leads to variations in reference voltage till the maximum Reactive power (RP) limit. When two Distribution Generators (DGs) touch, then it touches the limit of RP & voltage will decreases the voltage regulation limit i.e. still additional RP is required which is generated by DSTATCOM

Consider,

Power flow between two systems of machines [17] can be expressed as:

$$P_1 = \eta[R_{D1}(V_{11} - V\mathrm{Cos}(\delta_{11} - \delta)) + X_{D1}V\mathrm{Sin}(\delta_{11} - \delta)] \quad \ldots\ldots (1)$$

$$Q_1 = \eta[-R_{D1}V\mathrm{Sin}(\delta_{11} - \delta) + X_{D1}(V_{11} - V\mathrm{Cos}(\delta_{11} - \delta))] \quad \ldots\ldots (2)$$

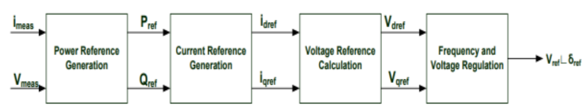


Figure.4 Block Diagram of Distributed Generator (DG)

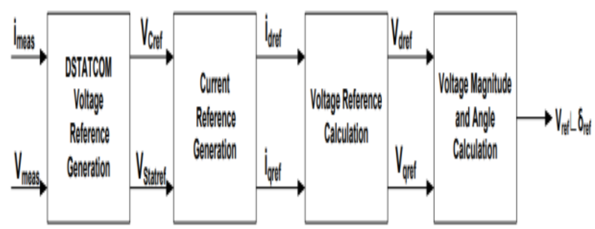


Figure.5 Converter control of DSTATCOM

The reference voltage of the DSTATCOM for the multi machine system [17] is shown:

$$V_{statref} = V_0 - m_{STAT}Q_{STAT} + K_1\frac{R_{D_1}P_1 + X_{D_1}Q_1}{V_{11}V_{22}} + K_2\frac{R_{D_2}P_2 + X_{D_2}Q_2}{V_{22}V_{33}} + K_3\frac{R_{D_3}P_3 + X_{D_3}Q_3}{V_{33}V_{stat}} + K_4\frac{R_{D_4}P_4 + X_{D_4}Q_4}{V_{44}V_{stat}} \quad \ldots\ldots (3)$$

It is considered as in case-1, the voltage dip is high at the far end of the feeder & DGs at far end is to get reactive current limit. In case-2, voltage at all locations will reduce the limit of voltage regulation. By using DSTATCOM (Distribution StaticCompensator), we can reduce the Reactive Power (RP) limit. DSTATCOM generated Reactive Power (RP) which increases the voltage to static synchronous compensator & also voltage in buses.

5. DISTRIBUTED GENERATORS STRUCTURE

The information about converter is illustrated in Table 2. Figure 4 denotes the control scheme of converter for DG-1. The voltage & frequency reference generation & current control loop is visualized in Figure 4. Figure 5 denotes the DSTATCOM control scheme. DSTATCOM (Distribution StaticCompensator) the voltage output is expressed in the equation (3). The DC voltage is hold on to settled Vcref & current reference generation is listed in Figure 5. The error produced in DC capacitor is feedback to PI controller to improve d-axis current ref, in DSTATCOM the output voltage utilizes the error to generate d-axis current ref. In [17], the various control strategies of DSTATCOM & DGs are illustrated. In case-1, DG produce maximum power. While in case-2, the frequency & voltage controls will droop. If DG comes to RP (Reactive Power) limit, the AP reference is varied. The representation of structure of converter DG-1 is illustrated in Figure 6. Mainly 1-phase converter consists of 4 IGBTs & converter AC side, output voltage is get back through transformer & output filter capacitor (Cf) is revealed in Figure 6. Transformer loss & Inductance are represented by Ltr & Rtr respectively. The Distributed Generator (DG) is combined with the PCC through output inductance (Lf).

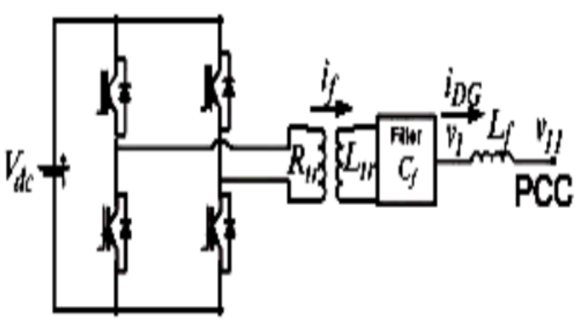


Figure 6. Indicates about Structure of DG Converter

In the first case, in the block of voltage reference calculation the reference voltage is fed back to converters. Generation of Reactive Power (RP) & Active Power depends on current limit of converter & noticed voltage control & frequency just operates in case-2 activity.

The Reactive Power (RP) maintains the voltage magnitude while the voltage angle is controlled by active power output.

VI. DSTATCOM CONVERTER STRUCTURE

Figure 7 shows a DSTATCOM Converter structure. The Capacitor Cdc & H-bridge inverter combination is connected at the DC side (input side) & the side of AC, esat is connected through output filter & transformer which appeared as Vsat & Istat respectively.

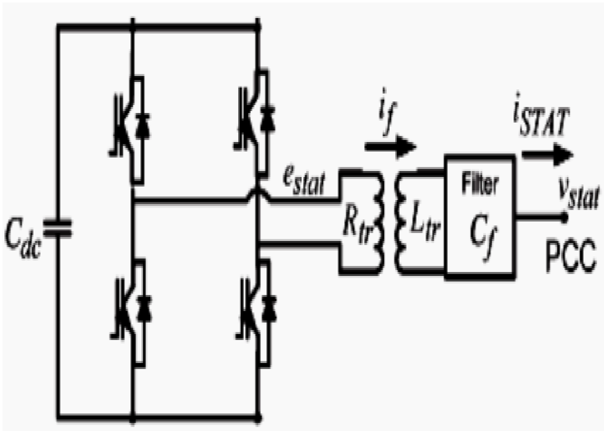


Figure 7. DSTATCOM Converter Circuit.

DSTATCOM Converter is varied by using instantaneous power theory, for voltage reference generation & phase angle.

VII. POWER NETWORK SIMULATION USING MATLAB

The system in Figure 1. Is simulated for various tests described as

Scenario 1: Indicates No RPC (Reactive Power Compensation)

Scenario 2: Indicates RPC (Reactive Power Compensation) on local measurements

Scenario3: Indicates RPC (Reactive Power Compensation) with great technique

In order to compare the execution by controller in each scenario, comparable arrangement of varying output power in the DGs (Distributed Generators) & switching load case is considered. Basically 3 different case situations to understand the efficiency of the proposed strategy listed below:

Case 1: Grid-connected mode

Case 2: Autonomous mode

Case 3: GridConnected followed with autonomous mode

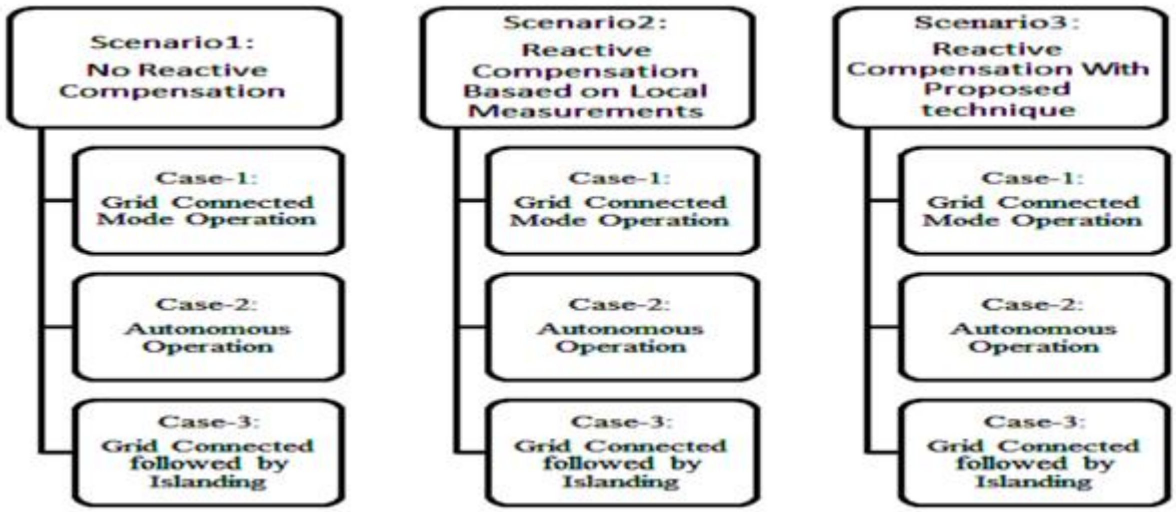


Figure 8. Different Test Cases.

The detailed explanation for each case given below:

Case-1: It is finalized that framework is working along with grid-connected mode. When the frame work in steady state, all DG's provide limited powers to all loads which are connected & in phase-a 3 DG's has power capacity up to 200W.

Case 2: It explains about the framework in islanded mode. When framework is in steady state with all DGs giving limited power & all loads are connected, 3 DG's connected to Bus-2 will produce output power up to 2000 W each. The Reactive Power also limits up to 400 VAR.

Case 3: It is explained that framework is in utility connected mode. In the steady state, all DGs generating limited power when all loads are connected, micro grid is islanded at 0.8 s & the DGs will supply load demand. At the time interval 1.1 s, DG (Distributed Generator) power output limited up to 2000 W. In order to eliminate the power request enter into microgrid say 2.0 s, loads which are connected at Bus-1 of Phase-B & Phase-A must be removed (17)

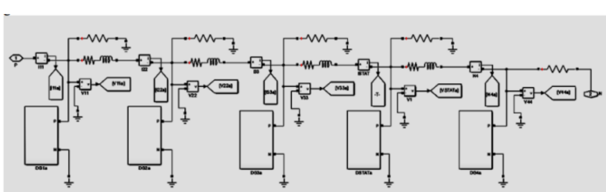


Figure.9 Describes about Simulation structure of multi-machine system.

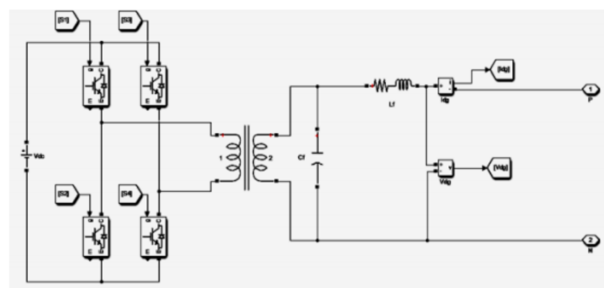


Figure 10. Simulation of DG Structure

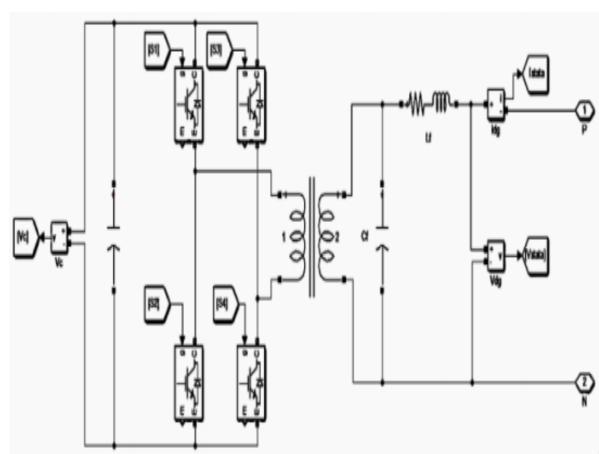


Figure 11. DSTATCOM Structure & its simulation

ISSN NO: 0042-9945

VIII. RESULTS

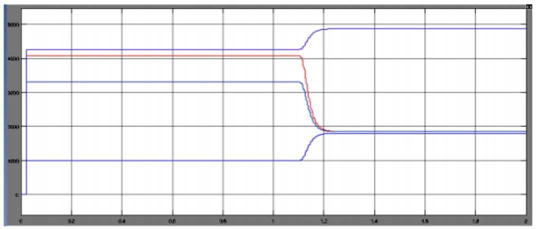


Figure.12 DG Power Output in phase-A (DGs)

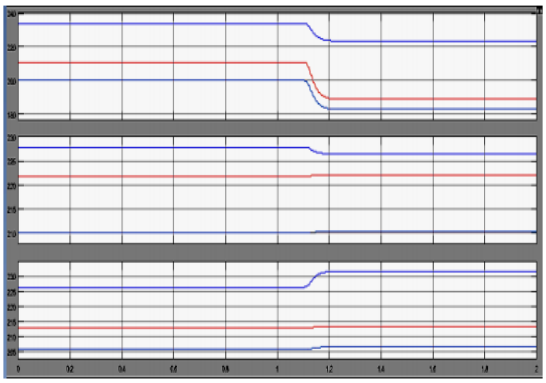
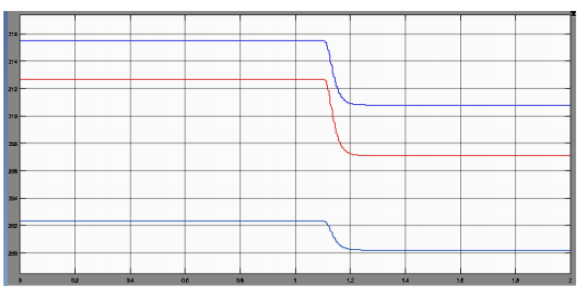
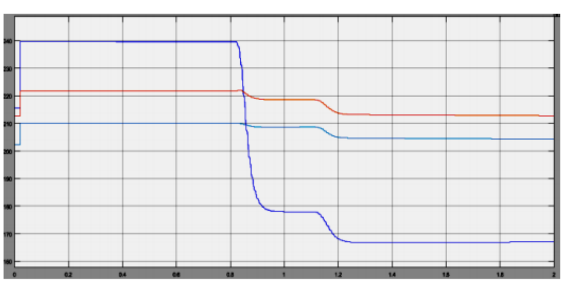


Figure.13 RMS voltage generated in three phases.



(a)



(b)

Figure.14.RMS voltages in (a) Case-2 (stage-A).
(b) Case-3 (stage-B).

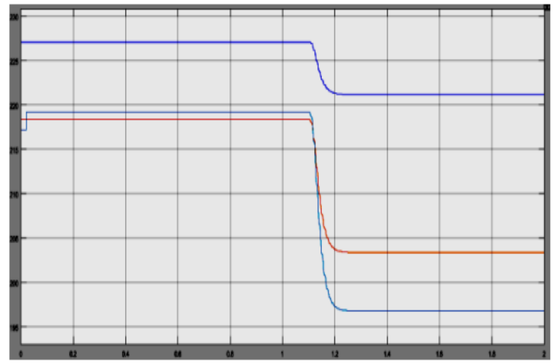
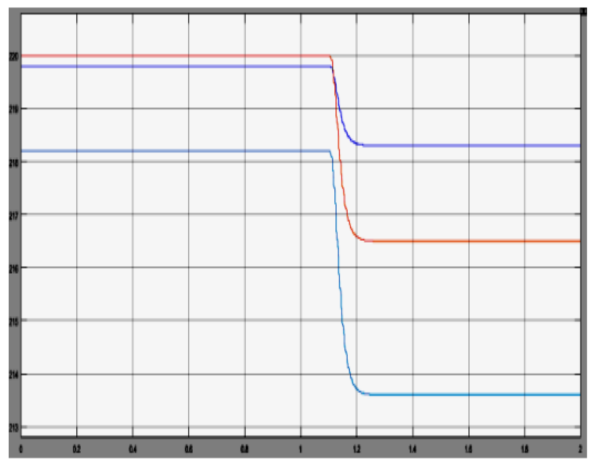
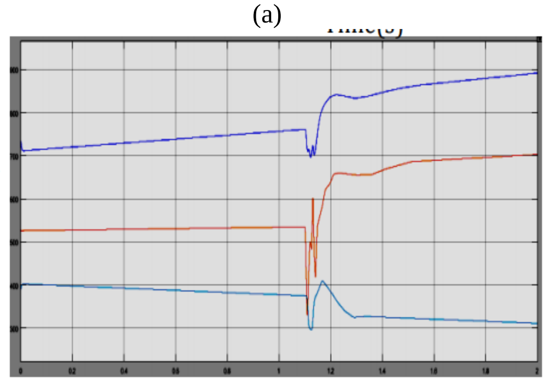


Figure.15 DSTATCOM. RMS voltage in Case-1 (phase-A)



(a)



(b)

Figure.16 (a) RMS voltage in various location.
(b) RP injected in 3 phases.

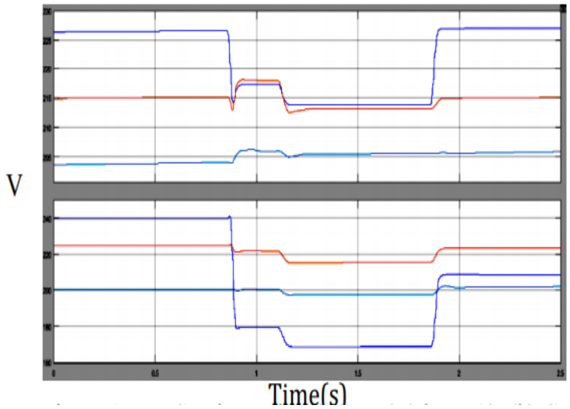
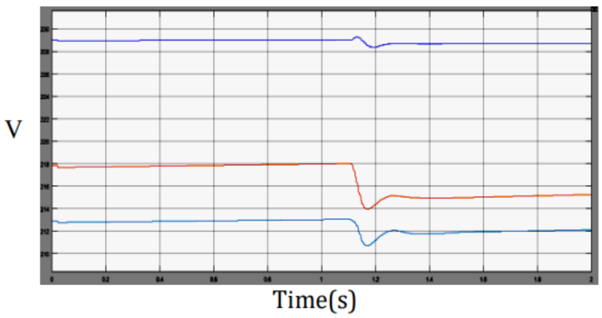
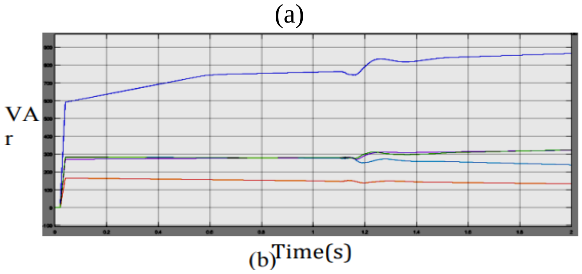


Figure.17 RMS voltages in (a) Case-3 (phaseA).(b)Case-3 (phase-B).



(a)



(b)

Figure.18 (a) RMS voltages in Case-1 with scenario-3;(b) RP injection of the DSTATCOM&DGs.

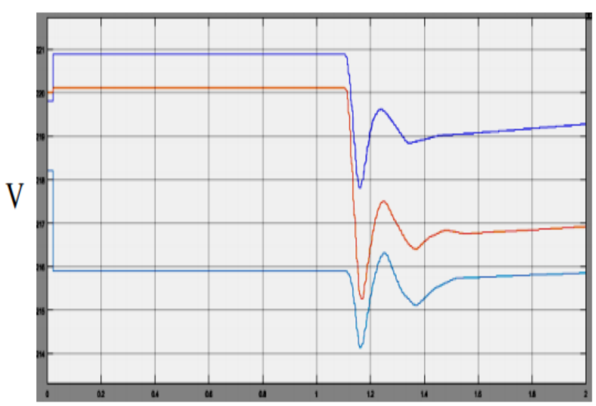
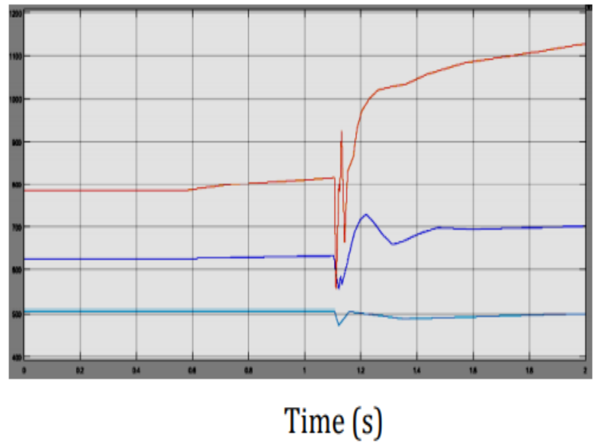


Figure.19 (a) RMS voltages in Case-2.



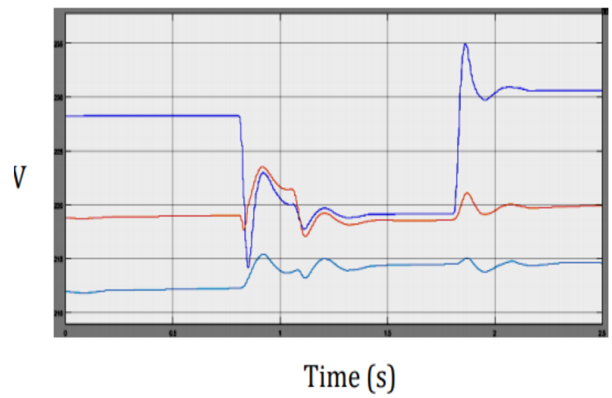


Figure.20 RMS voltages in Case-3 (Phase-A)

IX. CONCLUSION

This paper simulates a great control mechanism for DSTATCOM in a 1- Φ microgrid, to control the energy compensation. This scheme is implemented for microgrid feeding 1-Φ load with feeder's geographically segregated covering mini networks. The proposed RPC is based on nearby voltage calculation & power flow in lines. It is finalized that proposed strategy decreases voltagedrop in distributed generators (DGs). The MATLAB simulations of the considered framework with the proposed DSTATCOM shows the best results compared to other existing methods stated here in this paper. The future scope of developing a new model based on the communication networking is under research&the impacts will be studied to improve the quality of power

REFERENCES:

1. Robert H Lasseter, Ross T Guttromson, aAbbas An Akhil, A. Sakis Meliopoulous, Joseph H Eto, "Integeration of Distributed Energy Resources". CERTS microgrid thought. CERTS; Apr 2003.

2. Ronnie Belmans, Johan Driesen, "Circled Generation: Challenges&Possible Solutions". IEEE Power Engineering Society General Meeting; 1-4244-0493, 18-22 June 2006.

3. Yaosuo Xue, Liuchen Chang, Toshihisa Shimizu, Josep Bordonau, Sren Baekhj Kjaer, "Topologies of Single-Phase Inverters for Small Distributed Power Generators": A diagram, IEEE Trans.on Power Electronics., vol. 19, issue no. 5, 03 Sep. 2004.

4. Robert H. Lasseter. "MicroGrids," in IEEE, DOI: 10.1109/PESW.2002.985003, 07 August 2002.

5. Farid Katiraei, Reza Iravani, Nikos Hatziargyriou, Aris Dimeas, "Microgrids Management", IEEE Power&Energy Magazine, DOI:10.1109/MPE.2008.91872, 02 May 2008

6. Kao, Li, Y.W.; "An exact power control technique for control devices interfaced scattered age unit working in a low voltage Multi-transport microGrid". IEEE Trans. Power Electron. 2009.

7. Mahmud M, Hossain M, Pota, H, Oo, "A Robust Non-Linear Distributed Controller Design for dynamic&responsive power participating in Islanded Microgrid". IEEE Trans. Essentialness Convers. 2014

8. Souza W, Mendes M, Lopes L, "Power Sharing control Strategies for a three-organize Microgrid in different working Conditions with hang control&damping factor assessment". IET Proc. Reestablish. Power Gener. 2015.

9. NETL, U.S. Dept.of Energy, Provides Power Quality for 21st Century Needs, Jan. 2007.Ankita Palod&Vijaya Huchche, "Responsive Power Compensation Using DSTATCOM," IJEEDC, June-2015.

10. Majumdar,R; Arindam Ghosh; Ledwich,G;&Zare,F; "Overhauling the sufficiency of a self-administering microgrid using DSTATCOM," Int. J. Emerg. Pick. Power Syst., DOI: https://doi.org/10.2202/1553-779X.2227, Dec. 2009.

11. Majumdar,R; Arindam Ghosh; Ledwich,G;&Zare,F; "Balance control of converter-interfaced littler scale sources in nation appropriated age," IEEE Trans. Power Del., Oct. 2010.

12. Ledwich,G;&Arindam Ghosh; "A versatile DSTATCOM working in voltage or current control mode," Proc. Inst. Pick. Eng.— Gen., Transm. Distrib, Mar. 2002.

13. Majumdar,R; Arindam Ghosh; Ledwich,G;&Zare,F; "Action&control of single stage littler scale sources in an utility related cross section," in Proc. IEEE PES, Jul. 26–30, 2009.

14. Shuitao Y; Qin L; Peng F.Z;&Zhaoming Q; "A generous control plan for system related voltage-source inverters," IEEE Trans. Ind. Electron., Jan. 2011.