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Coordinated Control Algorithm for Integration of Multiple Microgrids at a Distribution Center

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ABSTRACT: With the rapid growth in demand for electricity in India, it is necessary to keep focus more on reliability and power quality aspects of conventional power grid. At the same time, due to urbanization stress on the conventional electric grid is also increased. So, as an augment to this in this paper “Microgrid (MG) Cluster” is formed by interconnecting neighbourhood microgrids in urban community level with interoperability. A Coordinated Control Algorithm (CCA) is also proposed to extract the energy effectively from the Renewable Energy Sources (RES) which are associated locally in all microgrids. The system considered for testing and the proposed algorithm both are modeled and developed in MATLAB 2016a software with Simulink tool box. The simulated results of the system under study show the fruitfulness of proposed CCA.

KEYWORDS: Microgrid (MG), Cluster, Coordinated Control Algorithm (CCA), Renewable Energy Sources (RES).

I. INTRODUCTION

In the world, India is one of the countries whose economy is growing very fast, and having population around 18% of world population with majority of the people residing in rural localities. The country placed at third for having highest rate in consumption of energy in the world. Moreover, India is struggling with lot of problems in maintaining the balance between the supply and demand. Because of this most of the rural areas are having no access to electrical power, even though they have integrated with the utility grid. In this country different types of microgrids were already deployed by central government and other state governments [1]. With the intermittent nature of RES used in the microgrid, mostly reliability in off grid mode depends on the capacity of storage systems. So that if the storage capacity increases that leads to increase in cost and maintenance issues. In order to avoid this situation adjacent microgrids are connected to improve the reliability. At the same time, single microgrid is not enough to meet the load requirements of consumers and it does not show much impact in reducing the stress on the utility grid. So to avoid the critical burden on the utility grid, microgrid cluster is formed along with utility at the level of distribution was introduced, to improve the reliability of distributed electrical power. So, Microgrids interconnection is the greatest possible solution to Indian power sector, with the key features of rural electrification, demand power, peak loads etc.

In the present scenario, because of higher energy requirements researches are emerging in the area of microgrids interconnection and technically interconnected microgrids is termed as “Microgrid Cluster”. The various techniques available to interconnect the microgrids are discussed in [2]. IEEE-1547 is best choice for network protections which are available on the grid side out of all the available standards. Some key features of interconnected and interoperable microgrids are listed below,

- Gives good support to the existing infrastructure of electric grid by including resilience.
- Supply the requirements of end users by providing UPS for critical peak loads.
- Maintains reliability and controls the power quality at local level.
- Make provision for modernization of grid and interoperability of multi Microgrids.

Enhances the integration of distributed and RES which helps to reduce CO₂ emissions, peak load obstruction, line losses by the generation nearer to demand. The schematic view of Microgrid Cluster is as shown in Fig. 1. The cluster contains four different building namely Residential Building (B1), Software Building (B2), Academic institute Building (B3), Manufacturing Industry Building (B4) with different load profiles associated with locally available green sources such as Solar PV, Wind and Fuel cell along with storage devices integrated and interconnected. Each is building is considered as a single microgrid. However this paper does not focus much on the modelling of RES, detailed modelling is given in [18]. As the renewable sources are intermittent in nature and also free to available, each microgrid is formed by considering combinations of free and paid sources. In this work fuel cell and storage system are considered as paid sources. The remaining paper is organized as follows: 1) Modelling of proposed control algorithm 2) Result analysis followed by 3) Conclusion.

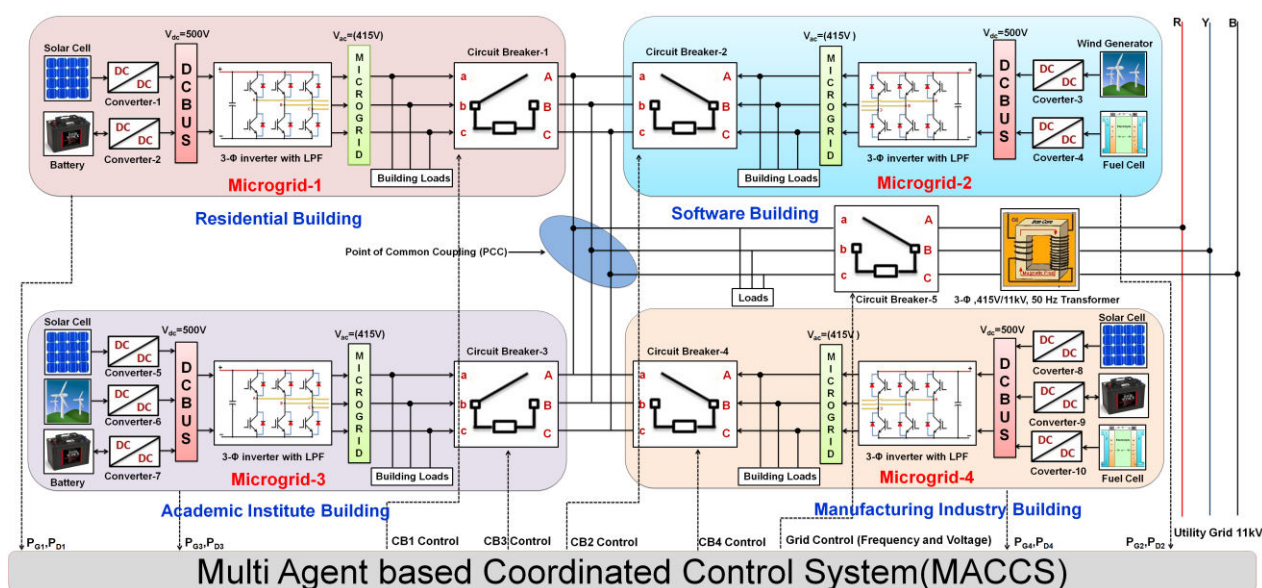


Fig. 1. General layout of Microgrid Cluster in Urban Community

II. RELATED WORK

Following are the some of the literature details of possible interconnection methods along with energy management control systems. Yanhong Yang et al [3] used coordination control methods along with mixed hybrid control methods for structure of interconnection and operation. Xing you Zhang et.al [4] proposed a model of multi microgrid system reliability which takes correlations of different microgrids in the system into account. Further the authors are also proposed reliability assessment algorithm along with proposed model. M. L. Herrera et al [5] proposed the possible interconnection configurations with two microgrids were along with control schemes, cost optimization schemes. This manages the power flow in the system considered. V. Kleftakis et al [6] introduced a new detection method for islanding in interconnected DC microgrids. Further this proposed method uses PI controller for sending the control signals to the storage system for maintain DC voltage during reconnection. S. Maiti et al in [7] presented a load flow converter (LFC) used to interconnect two neighboring DC microgrids which also controls the power flow in the interconnected system. This LFC injects a voltage in series with the line for controlling the power. M. L. Herrera, et al [8] presented some investigations on control methods and operation strategies of interconnected microgrids with respect to frequency stability and optimizing cost. N. Bayati, et al [9] proposed a distributive poverty index for providing protection for interconnected DC microgrid cluster. The protection of the system is verified by considering different faults.

Igualada et al [10] proposed an energy management algorithm of a residential microgrid with realistic electric vehicle to grid capability which consists of arrival, departure timings of vehicle and its SOC, load profiles, functioning of microgrid components. J. Shen et al [11] proposed a novel EMS to provide load levelling to the grid. With peak time rebate the DR schemes; control units are takes part in the response program along with two new index terms for evaluating the performance of microgrid. Heymann B et al [12] proposed a new energy management strategy for microgrid by introducing a formulation of continuous in time, rolling horizon. In this the management problem is

considered as a problem of deterministic optimal control. Luu Ngoc et al [13] presented an EMS for a microgrid operated in grid connected mode. The purpose of EMS is to minimize the cost and also to reduce the power import from utility grid. M. Strelec and J. Berka [14] adopted dynamic programming (approximated) (ADP) as a solution to optimization problem of energy management and also policy search way to ADP and selected architectures in the context of energy management. H. Kanchev et al [15] discussed the solution for the problem of optimum operational planning in the presence of prosumers. A coordinated control strategy for managing the sources through a communication network was proposed. N. Tiwari and L. Srivastava [16] proposed differential evaluation based EMS for optimizing the performance of microgrid in the presence of renewable sources. In order to cover the uncertainty the DR programs are also included in the EMS. M. Yu et al [17] proposed revised DE algorithm with self-adaptive controlling the parameters of microgrid for the energy management. Improved DE uses fitness variance to solve the optimization problem. In this paper a frame work for development of a hierarchical multi agent based control system is modeled for interoperable microgrids at urban community level.

III. COORDINATED CONTROL ALGORITHM

As per the international standard IEC 61970 an Energy Management System (EMS) is an information system on software platform, which facilitates the functionalities when supported on a platform to provide generation, transmission and distribution of electrical energy at a low price [44]. Management of energy in microgrids is control algorithm developed in a computer to have the optimal operation of the system [45]. In general EMS contains some modules such as machine interfacing and SCADA (Supervisory Control and Data Acquisition Systems) which performs strategies in decision making. The various functions of EMS are monitoring the data, data analytics, load prediction, optimization and electricity prices in deregulated energy market.

A Proper Energy Management System (EMS) is necessary to monitor and control the operation of microgrids (MG) to obtain the required objectives. Due to the integration of more Distributed Generations (DG), storage systems and critical loads operation of MG is more complicated particularly when microgrids are interconnected and interoperable when compared to conventional system. EMS designed to control the operation of MG is different from conventional power system. The implementation of proposed algorithm in sequence form is given in Table 1 and flow chart for the implementation of local agent control of i^{th} MG is shown in Fig. 2.

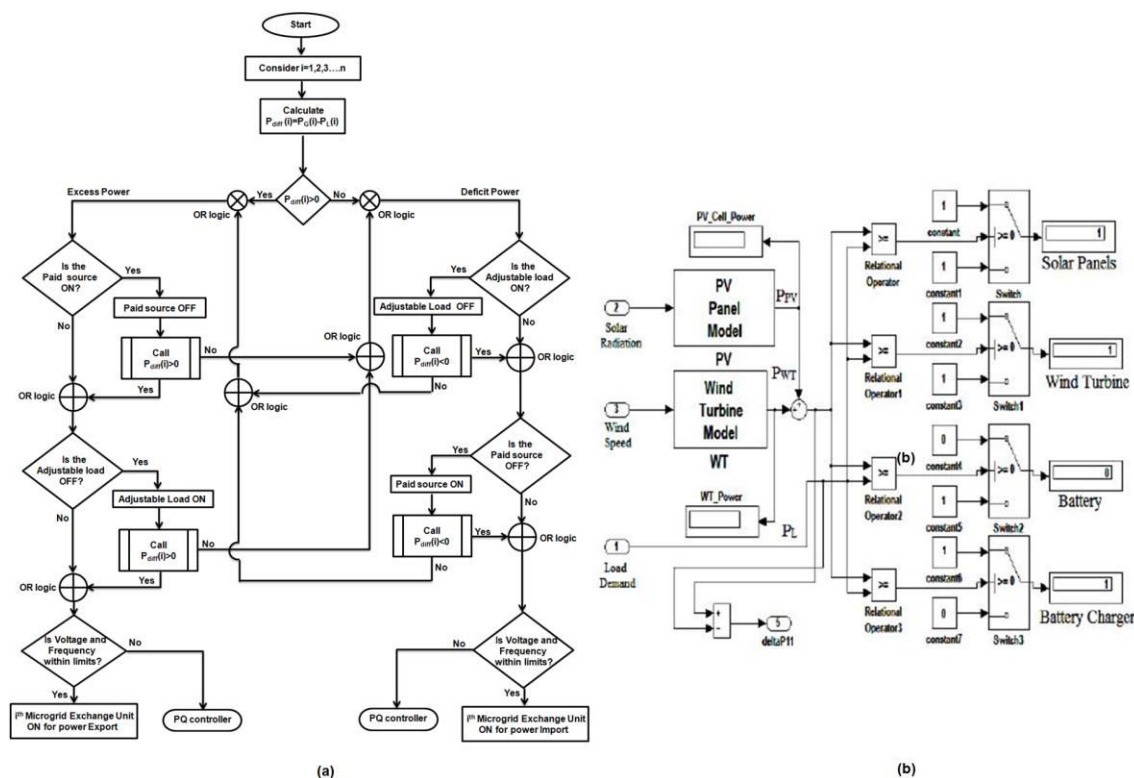


Fig.2 Flow chart for implementing a) Local control agent of i^{th} MG b) Resources management in i^{th} MG

Table1. Algorithm steps for the implementation of local agents of i^{th} Microgrid

Step-1: Calculate the power differences of all microgrids by taking the difference between generated powers and demand powers.

Step-2: Initialize the microgrid numbers as i, j .

Step-3: If $P_{\text{diff}, i} > 0$, means that the power generated at i^{th} MG is excess than load demand.

Step-4: If $P_{\text{diff}, i} < 0$, means that the load demand is more and hence, need to obtain the power from adjacent buildings or from the electric grid.

Step-5: Similarly, obtain the difference of powers from remaining microgrids 2, 3, and 4 and if the generated power at any microgrid is available in excess, which has to be transferred to 1st microgrid as per its need.

Step-6: still if the net power available at microgrid-1 is deficit even though the power supplied by other buildings either individual or in group then the shortage power can be imported from utility grid. The central coordinated control unit will communicate with other building agents in these cases.

The same sequence is followed for the remaining microgrids for proper operation, thereby controls the power flow at community level. This reduces the extra stress created on utility grid.

IV. SIMULATION RESULTS

The MATLAB/Simulink modeling of microgrid cluster is as shown in Fig. 3. In this section the power differences in all the microgrids from MG_1 to MG_4 which are connected in cluster is as shown in Fig 4(a) to Fig 4(d). It is to note that the figure 4 shows the power differences in the cluster when individual building is connected integrated with the electric grid. From the results shown in Fig. 4, it is observed clearly that the need of connecting four green buildings at urban community level which reduces the net power imported from the grid thus reduces the additional burden.

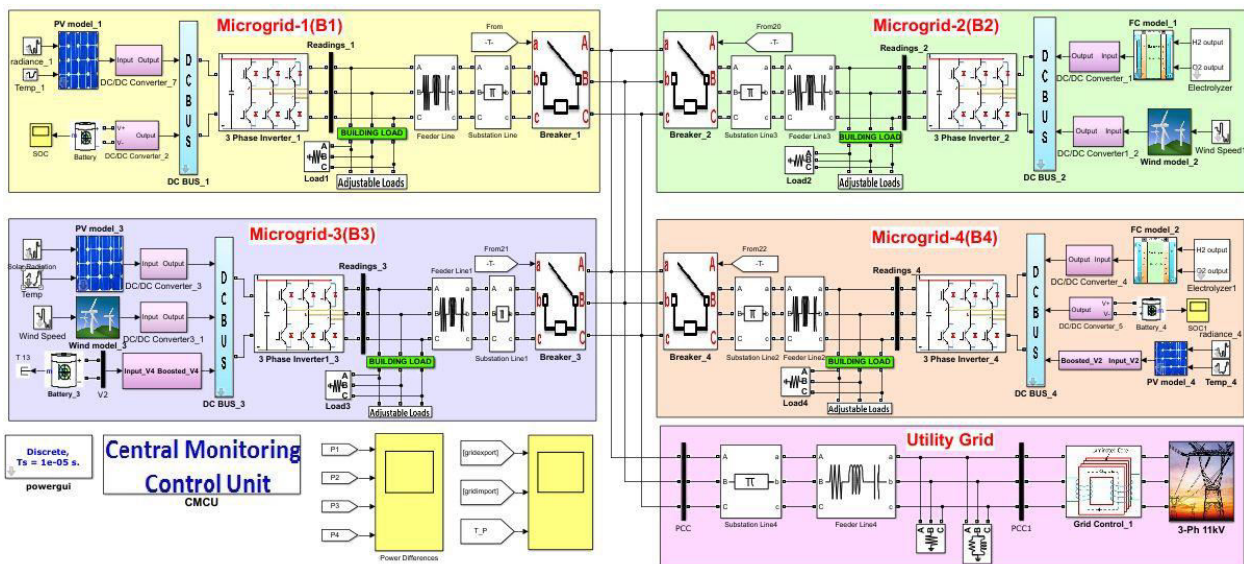


Fig.3 Microgrid Cluster implemented in MATLAB/Simulink

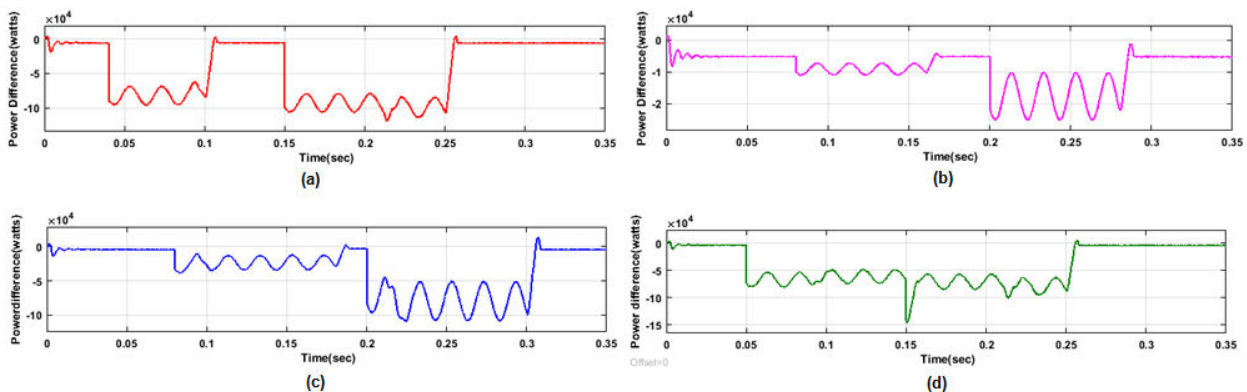


Fig.4 Power differences ($P_{diff}=P_G-P_D$) of a) Residential Building(MG_1) b) Software Building (MG_2) c) Academic Institute Building (MG_3) d) Manufacturing Industry Building (MG_4) are alone connected to utility grid

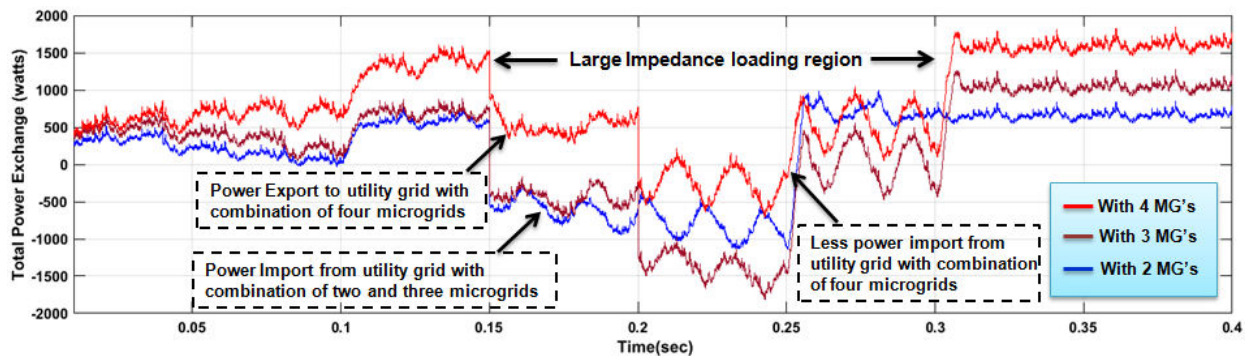


Fig.4 illustration to show the advantage of considering four urban green microgrids with interoperability to form a microgrid cluster for making energy transactions (Import/Export) with the utility grid during excess/deficit power conditions

Figure 5 clearly shows that the net power available at PCC of a cluster that is ready to import or export to/from utility grid during shortage/surplus power conditions. Table 2 gives the amount of power at each building in a cluster at different instants of time with microgrid alone and with the combinations of two, three and four microgrids in a grid connected mode.

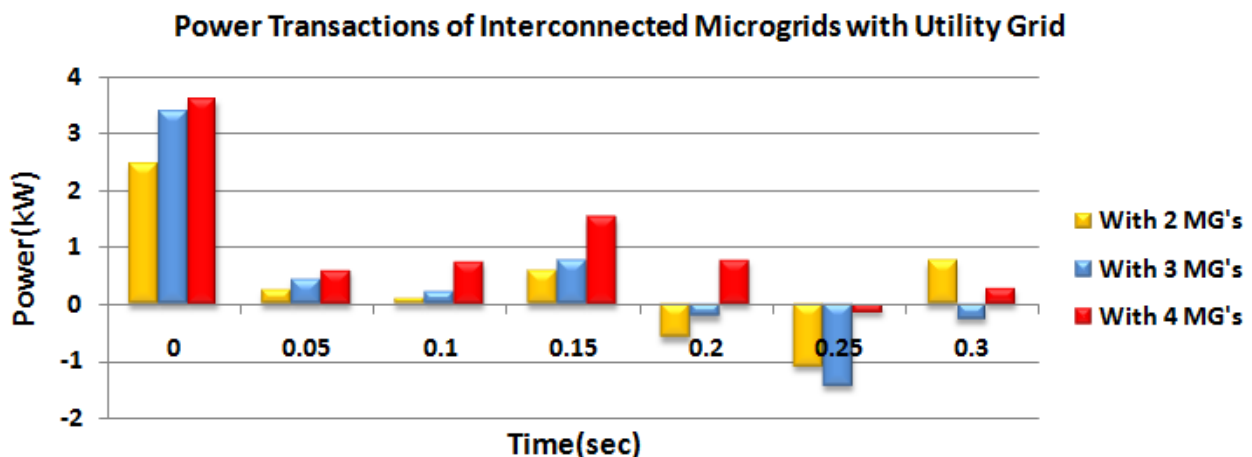


Fig.5 Power (kW) available at PCC of cluster at different instants of time

Table 2: Energy Transactions Details of cluster with utility grid during Excess/Deficit power conditions

Microgrid combination	Power available at PCC of microgrid cluster in kW for making energy transactions with utility grid.					
	T=0.1S	T=0.15S	T=0.2S	T=0.25S	T=0.3S	T=0.35S
MG ₁ (Alone)	-83.63(D)	-5.43(D)	-86.41(D)	-106.45(D)	-5.92(D)	-5.95(D)
MG ₂ (Alone)	-10.09(D)	-8.29(D)	-5.22(D)	-14.13(D)	-5.24(D)	-0.25(D)
MG ₃ (Alone)	-27.46(D)	-18.85(D)	-3.68(D)	-64.02(D)	-95.56(D)	-4.78(D)
MG ₄ (Alone)	-53.84(D)	-68.14(D)	-64.32(D)	-86.61(D)	-4.02(D)	-4.03(D)
MG ₁ ,MG ₂	0.1(E)	0.6(E)	-0.59(D)	-1.09(D)	0.76(E)	0.67(E)
MG ₁ ,MG ₂ ,MG ₃	0.22(E)	0.76(E)	-0.22(D)	-1.43(D)	-0.026(D)	1.05(E)
MG ₁ ,MG ₂ ,MG ₃ ,MG ₄	0.75(E)	1.53(E)	0.78(E)	-0.14(D)	0.28(E)	1.6(E)

*E- Excess (Power Exported to Grid), D-Deficit (Power Imported from Grid)

V. CONCLUSION

This paper gives the insight into the formation of microgrids cluster in Indian power scenario at urban community. The proposed algorithm allows the cluster to make the energy transactions with the utility grid during shortage/surplus power conditions. The major objective of this paper is to integrate the urban community buildings viz., residential flats, software companies, universities etc. The major advantage of in these systems is proposed control approach effectively manages the resources in cluster and indiscriminately diminished the additional stress on the conventional electric grid system. The fruitful behaviour of proposed control strategy is verified from the obtained results.

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