OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Improving Distribution Feeders for Photovoltaic Generation by Loop Power Control Method

Husam Saad Abdulla[1], Surya Prakashline[2]
[1](Libyan Electricity Ministry/ University SHIATS, India)
[2](Electrical Engineering Department, SHIATS, India

ABSTRACT: *Now a day's solar power plants are more reliable, because no fuel and reduced CO2 emission. But the solar power generation system do not work in all weather conditions, it is power generated only solar radiation time .To overcome this problem by using (pv)). In fuel cell power generation there will be no problems, where as in fuel cell power distribution systems have some problems like overloading the distribution feeders. In this project to overcome this overloading by using Loop Power Controller (LPC).The loop power controller to control real power and reactive power flow by adjusting voltage ratio and phase shift. Daily loading unbalance is determined by analyzing (pv) power generation recording by using SCADA system and load profile based on Data Automation System (DAS).The loop power controller can improve controllability, operational flexibility and reduce power loss of the distribution system. The Loop Power Controller (LPC) is based on the MATLAB/ SIMULINK.*
Keywords: *Power, Distribution Grid, solar power, Loop Power Controller.*

I. Introduction

Renewable energy resources such as wind turbines, hydrogen turbines and photovoltaic arrays are environmental friendly. This type of generations rapidly increasing around the world because they can increasing the demand of electric power and to decrease the green house gases. Penetration of wind power generation and PV power generation into distribution systems is expected to increase dramatically, which raises concerns about system impact by the intermittent power generation of DG [1]–[3]. Compared to large-scale wind power and conventional bulk generation, the generation cost of a PV system is relatively higher However, many countries offer significant financial subsidies to encourage customers to install PV systems. To achieve the goal of 1000 MW PV installed capacity by 2025, the Taiwan government has launched a promotion program to subsidize 50% of the PV installation cost and has increased the selling price of PV generation to 40¢/kWh [4]. Considerable efforts have been proposed in the previous works to solve the loading balance of distribution systems. The distribution static compensator (DSTATCOM) was considered for compensation of loading unbalance caused by stochastic load demand in distribution systems [6]. The control algorithm for static var compensation (SVC) has been developed for loading balance at any given power factor [7]. Fuzzy multi objective and Tabu search have been used to optimize the on/off patterns of tie switches and sectionalizing switches to achieve feeder loading balance in distribution systems with distributed generators [8]. A heuristic-expert system approach for network reconfiguration to enhance current balance among distribution feeders was presented by Reddy and Sydulu [9]. A Petri-Net algorithm has also been proposed for loading balance of distribution systems with open loop configuration by identifying open-tie switches [10]. For the distribution system with large capacity of PV installation, the feeder loading will be varied dramatically because the power injection by PV generation is varied with the intensity of solar radiation. The load transfer between feeders with an open-tie switch must be adaptively adjusted according to PV power generation. Due to the intermittent power generation by PV systems, it becomes very difficult to achieve loading balance with conventional network reconfiguration methods by changing the status of line switches. With the advancement of power electronics, the back-to-back (BTB) converters can be applied to replace the open-tie switch for better control of real power and reactive power load transfer by changing the voltage ratio and phase shift between two feeders according to the power unbalance at any time instant [11]. For the distribution system with high penetration of renewable energy sources, voltage profiles and loading balance have to be enhanced by improving the power exchange capability between feeders. This study pro- poses a loop power controller (LPC) [12], [13] to replace the conventional open-tie switch so that loading balance of distribution feeders can be obtained by power flow control in a more active manner. A transformer less converter with snubberless insulated gate bipolar transistor (IGBT) is applied to the proposed LPC using an active-gate-control (AGC) scheme. The AGC scheme can balance the collector voltage of IGBTs connected in series and allow the converter to connect directly to distribution feeders with a high enough AC voltage output [14]. Additionally ,LPC canreduce the voltage fluctuation and system power loss by enhancing reactive power compensation. In this paper, the three-phase balanced flow condition is assumed for both distribution feeders to perform the load transfer by LPC. The design of the LPC control strategy must consider intermittent power injection by PV generation and varying feeder loading so that the loading unbalance and system power loss can be minimized in each study hour. This paper is organized as follows. First, Section II introduces the distribution automation system with a loop power controller. Section III presents the feeder loading balance simulation and LPC control algorithm. In Section IV, the impact of the PV system on feeder loading balance and loss reduction of the distribution system is investigated. Finally, Section V gives conclusions.

II. Loop Power Controller In Distribution Automation System

The distribution automation system (DAS) as shown in fig .1 its take to reference from taipower station. The DAS consists master station (MS) with software application, remote terminal unit (RTU) and feeder terminal unit (FTU) in substation. The distribution feeders are connected as open loop configuration with one of the automatic line switches selected the open tie switch. In open loop configuration feeder having circuit breaker, when fault occurs in feeder the circuit breaker will be trips, the over current fault flags of all upstream FTUs are set due to large fault currents, after the all fault flags are received in master station. The master station sends command to open all line switches by using the open tie switches around the faulted location, after clearing the faults the feeder has to be recloses.

In DAS fault restoration effectively in taipower, but balance of loading is difficult in distribution system because the switching operation is required too frequently, to overcome the problem we are proposing the LPC, it is applied to replace open tie switch by adaptive power flow control for load transfer. The advantages of LPC in distribution feeder pair, 1) reduce the voltage fluctuations with fast compensate the reactive power. 2) The real power an reactive power is controlled. 3) In the distribution system controllability operation flexibility is improved. 4) Reduced power system losses with improved load balance of distribution system.

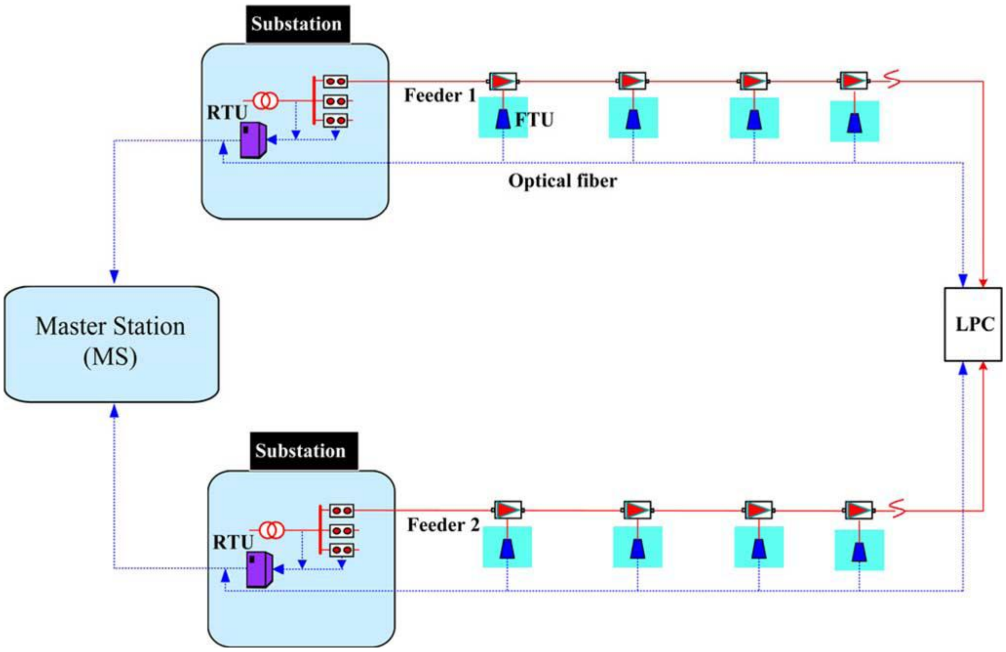

Fig .1: Distribution automation system with a loop power controller

III. Control Model of Loop Power Controller

To derive the voltage ratio and phase shift of LPC for the control of load transfer, the equivalent circuit model of LPC is proposed by considering the branch impedances of distribution feeders for the simulation of feeder loading balance. Fig. 2 shows the overall process to derive the LPC control algorithm to enhance loading balance of distribution feeders.

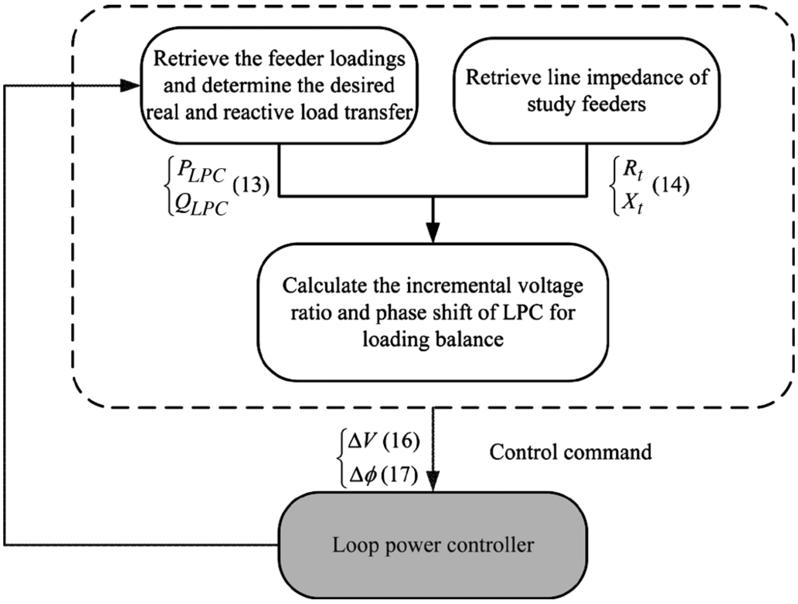

Fig2: Flowchart of LPC control algorithm**.**

A. simulation of feeder loading balance

In this study, the LPC is considered as the combination of tap changer and phase shifter with a circuit model as shown in Fig. 3. By adjusting the voltage ratio and phase shift between both sides of the LPC according to the branch impedance and loading unbalance of distribution feeders, the real and reactive power flows through the LPC can be controlled to achieve the loading balance. The equivalent circuit model can be represented as an ideal transformer with turn ratio of $1{:}ne^{j\emptyset}$ and a series admittance y.

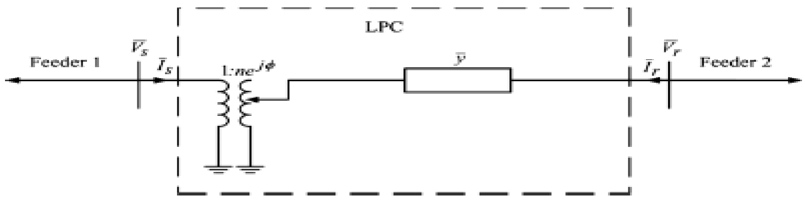

Fig3: Circuit model of loop power controller**.**

The mathematical model of LPC can be illustrated in (1) to represent the relationship between the node injection currents and voltages:

$$\begin{bmatrix} \bar{I}_s \\ \bar{I}_r \end{bmatrix} = \begin{bmatrix} |n|^2\bar{y} & -\bar{n}^*\bar{y} \\ -\bar{n}\bar{y} & \bar{y} \end{bmatrix} \begin{bmatrix} \bar{V}_s \\ \bar{V}_r \end{bmatrix} \quad \text{.......(1)}$$

where $\bar{n} = ne^{j\phi}$.

To simplify the process to determine the voltage ratio and phase shift of LPC, this paper proposes a modified equivalent circuit with dependent currents source and as shown in Fig. 4. Here, the dependent current sources are revised according to the adjustments of turn ratio and phase shift during the iteration process. To derive the injection currents due to the change of voltage ratio by LPC, the node currents are represented by assuming zero phase shifts as follows:

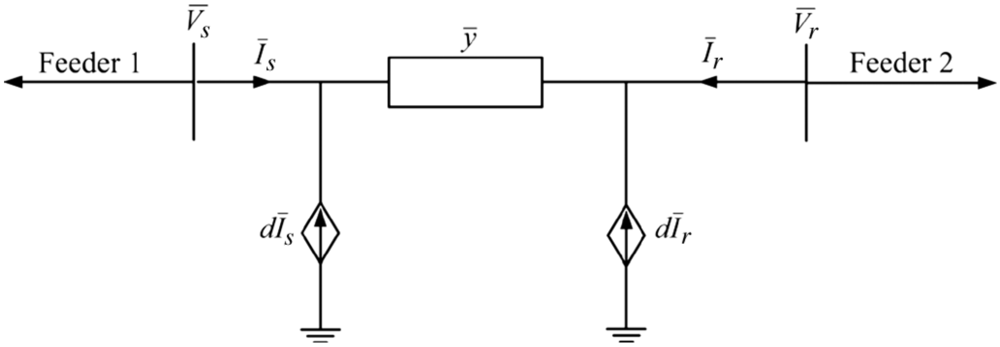

Fig4: Modified equivalent circuit model of LPC.

$$\begin{aligned} I_s &= n^2\bar{y}\bar{V}_s - n\bar{y}\bar{V}_r \\ &= (n^2-1)\bar{y}\bar{V}_s + (1-n)\bar{y}\bar{V}_r + \bar{y}(\bar{V}_s - \bar{V}_r) \end{aligned} \quad \text{………(2)}$$

$$\begin{aligned} I_r &= -n\bar{y}\bar{V}_s + \bar{y}\bar{V}_r \\ &= (1-n)\bar{y}\bar{V}_s + \bar{y}(\bar{V}_r - \bar{V}_s). \end{aligned} \quad \text{……….(3)}$$

The equivalent injection currents are solved as

$$dI_s' = -(n^2-1)\bar{y}\bar{V}_s - (1-n)\bar{y}\bar{V}_r \quad \text{…………..(4)}$$

$$dI_r' = -(1-n)\bar{y}\bar{V}_s. \quad \text{…………..(5)}$$

To derive the injection current due to the change of phase shift by LPC, the node currents are represented by assuming a fixed voltage ratio of 1.0 as follows:

$$\begin{aligned} I_s &= \bar{y}\bar{V}_s - \bar{y}e^{-j\phi}\bar{V}_r \\ &= (1-e^{-j\phi})\bar{y}\bar{V}_r + \bar{y}(\bar{V}_s - \bar{V}_r) \end{aligned} \quad \text{…………(6)}$$

$$I_r = (1-e^{j\phi})\bar{y}\bar{V}_s + \bar{y}(\bar{V}_r - \bar{V}_s). \quad \text{…………(7)}$$

The equivalent injection currents are solved as

$$dI_s'' = -(1-e^{-j\phi})\bar{y}\bar{V}_r \quad \text{…………(8)}$$

$$dI_r'' = -(1-e^{j\phi})\bar{y}\bar{V}_s. \quad \text{…………..(9)}$$

Therefore, the equivalent currents due to the change of both voltage ratio and phase shift by LPC in Fig. 4 are determined as follows:

$$dI_s = dI_s' + dI_s'' \quad \text{…………(10)}$$

$$dI_r = dI_r' + dI_r'' \quad \text{…………(11)}$$

$$\begin{bmatrix} d\bar{I}_s \\ d\bar{I}_r \end{bmatrix} = \begin{bmatrix} (1-n^2)\bar{y} & (n+e^{-j\phi}-2)\bar{y} \\ (n-1)\bar{y} & (n+e^{j\phi}-2)\bar{y} \end{bmatrix} \begin{bmatrix} \bar{V}_s \\ \bar{V}_r \end{bmatrix} \quad \text{……….(12)}$$

By this way, the network impedance matrix remains unchanged during the iteration process to solve the voltage ration and phase shift of LPC.

B. loop power control Algorithm

To illustrate the proposed control algorithm for LPC to achieve feeder loading balance, consider the two sample radial feeders connected with an LPC in Fig. 5. The desired real and reactive power flows through the LPC for feeder loading balance are defined as

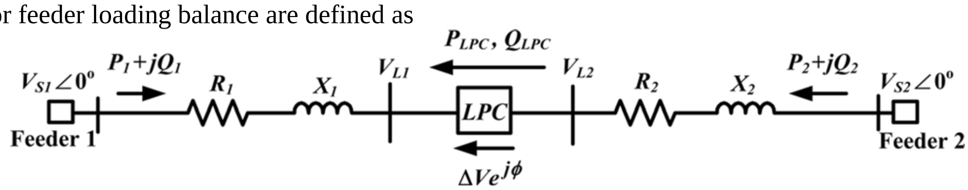

Fig. 5: Incremental circuit model of distribution feeders with LPC.

$$\begin{cases} P_{LPC} = \frac{P_1 - P_2}{2} \\ Q_{LPC} = \frac{Q_1 - Q_2}{2} \end{cases} \quad \text{............(13)}$$

If the branch impedances of Feeder 1 and Feeder 2 are (R_1, X_1) and (R_2, X_2) , respectively, the total impedance of two feeders is defined as

$$\begin{cases} R_t = R_1 + R_2 \\ X_t = X_1 + X_2 \end{cases} \quad \text{............(14)}$$

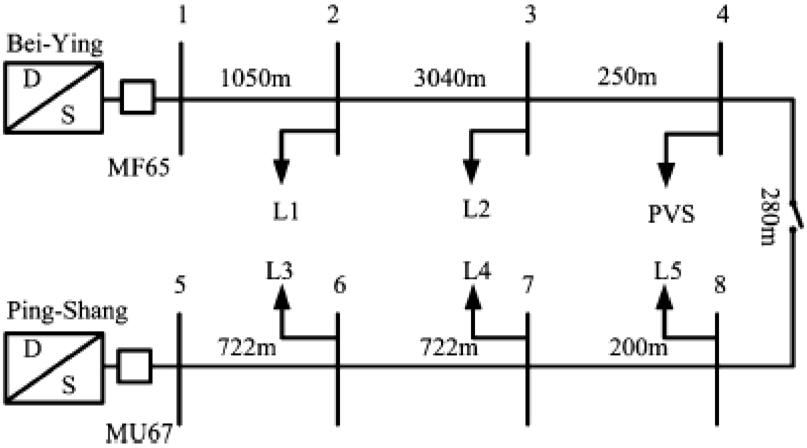

Fig. 6: Taipower distribution feeders for computer simulation.

In order to perform the LPC control strategy to have the proper load transfer between both feeders for loading balance, the terminal voltage V_{L1} at the primary side of LPC is assumed to have a fixed value of $1.0\angle 0°$. The terminal voltage at the secondary side of LPC is derived in (4.15):

$$|V'_{L2}| = \sqrt{(1 + P_{LPC} R_t + Q_{LPC} X_t)^2 + (P_{LPC} X_t - Q_{LPC} R_t)^2} \quad \text{..........(15)}$$

The incremental terminal voltage ΔV and phase shift $\Delta Ø$ are therefore calculated as follows:

$$\Delta V = |V'_{L2}| - 1.0 \quad \text{..........(16)}$$

$$\Delta\phi = \tan^{-1} \frac{P_{LPC} X_t - Q_{LPC} R_t}{1 + P_{LPC} R_t + Q_{LPC} X_t} \quad \text{...........(17)}$$

IV. Loading Balance and Loss Analysis Using LPC In and Distribution Feeder

With the variation of customer loading profiles and the intermittent generation of PV systems, an adaptive LPC control algorithm is derived to adjust the voltage ratio and phase shift between both feeders according to the feeder loading and PV generation for each study hour. To illustrate the effectiveness of LPC for system loading balance, an LPC is assumed to be installed to replace the open-tie switch between Feeders.

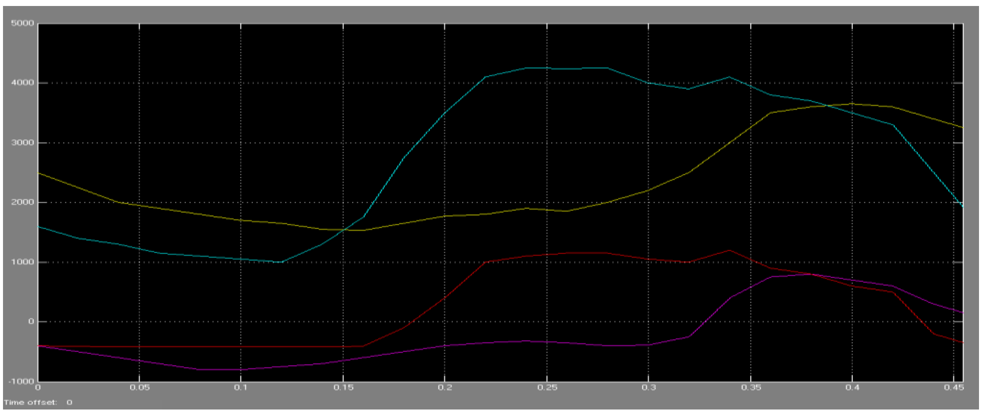

Fig.7:Balancing The Load Of Power Profile Of Feeder 1and 2 Without Photovoltaic System

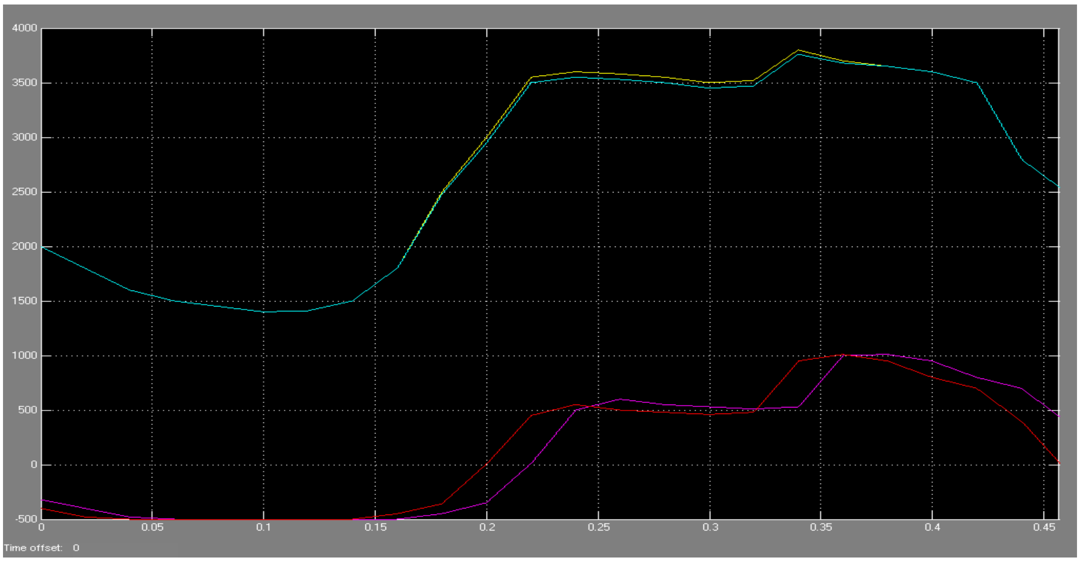

Fig 8: Balancing the Load of Both Feeders with the Control of LPC (W/O Photovoltaic System

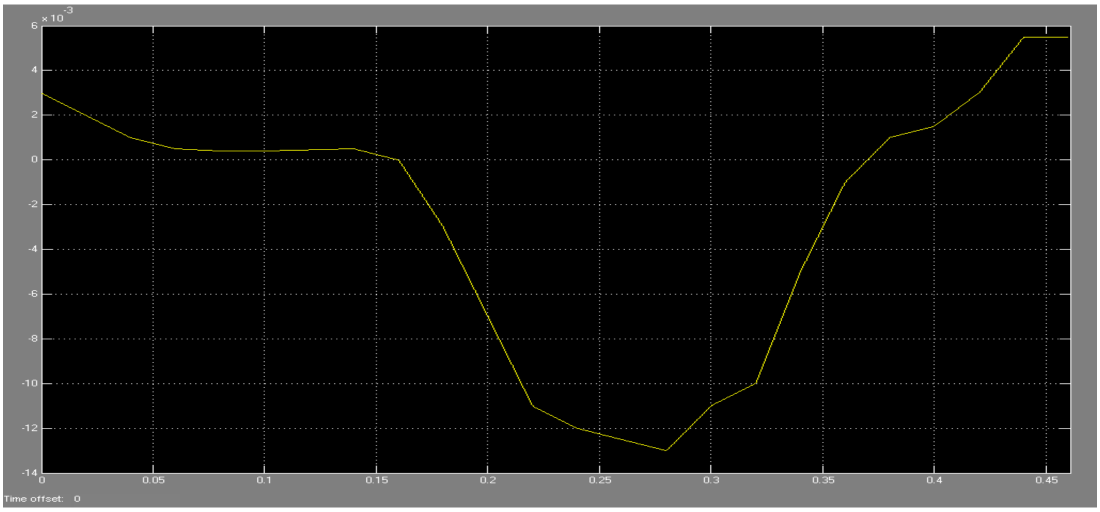

Fig 9: Voltage Ratio for power transfer With the Control of LPC (W/O The PV System)

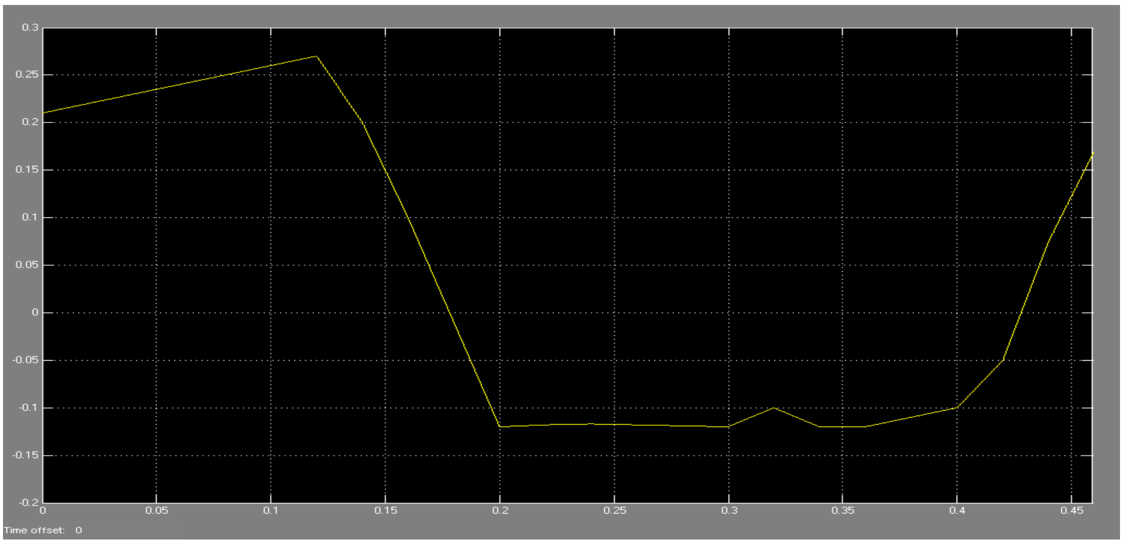

Fig 10: phase shift with the control of LPC (W/O The PV System).

after execution the real power and reactive power load profile of two feeders without PV system power as show in fig .8 , the distribution feeders to achieve the load balance using LPC only , the real power and reactive power difference between feeder MF65 and MU67 to be reduced from 1864KW/1715KVAR to 170KW/71KV after connecting LPC for power flow control. and the voltage ratio and phase shift also show in fig.9 and fig 10 respectively after connecting LPC.

V. Loading Balance When Using Both PV & LPC

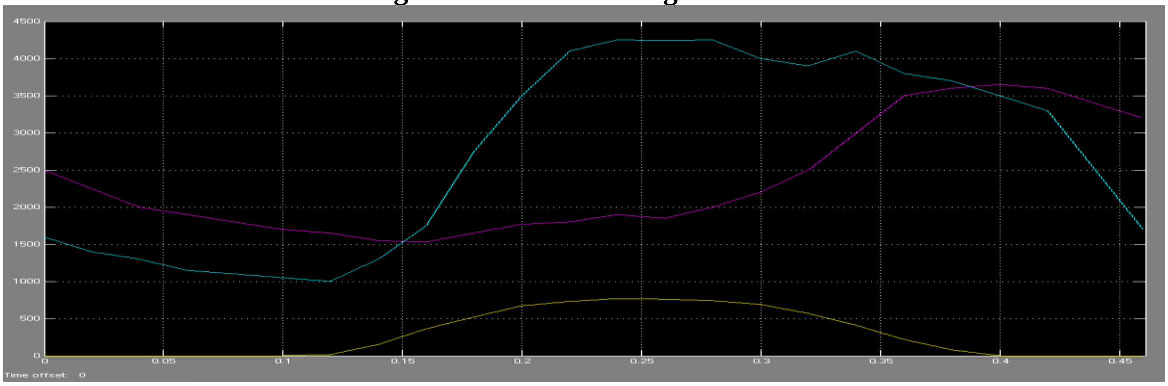

Fig 11: power profiles of feeder MF65 and MU67 for both PV&LPC.

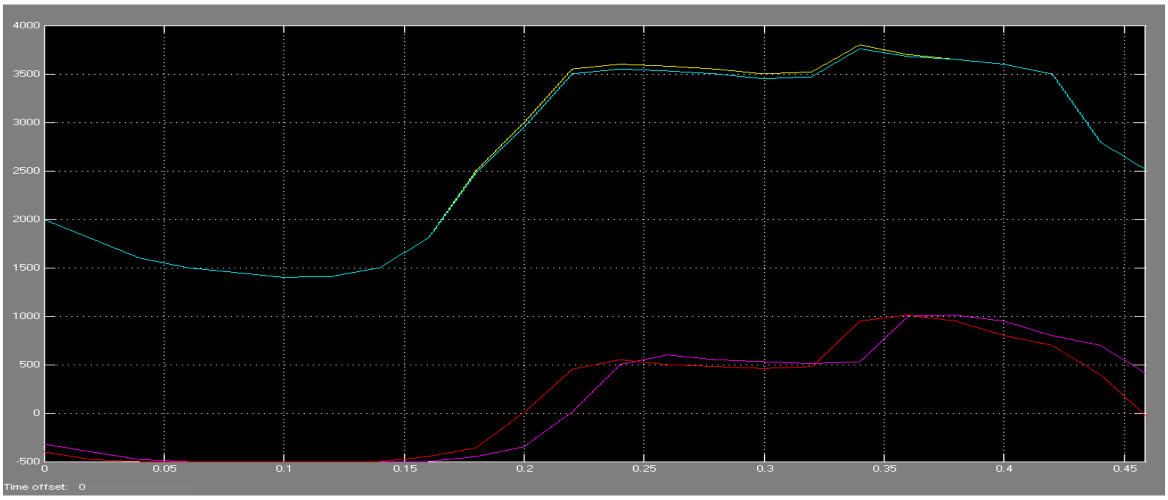

Fig 12: Loading balance of both feeders with the control of LPC & PV.

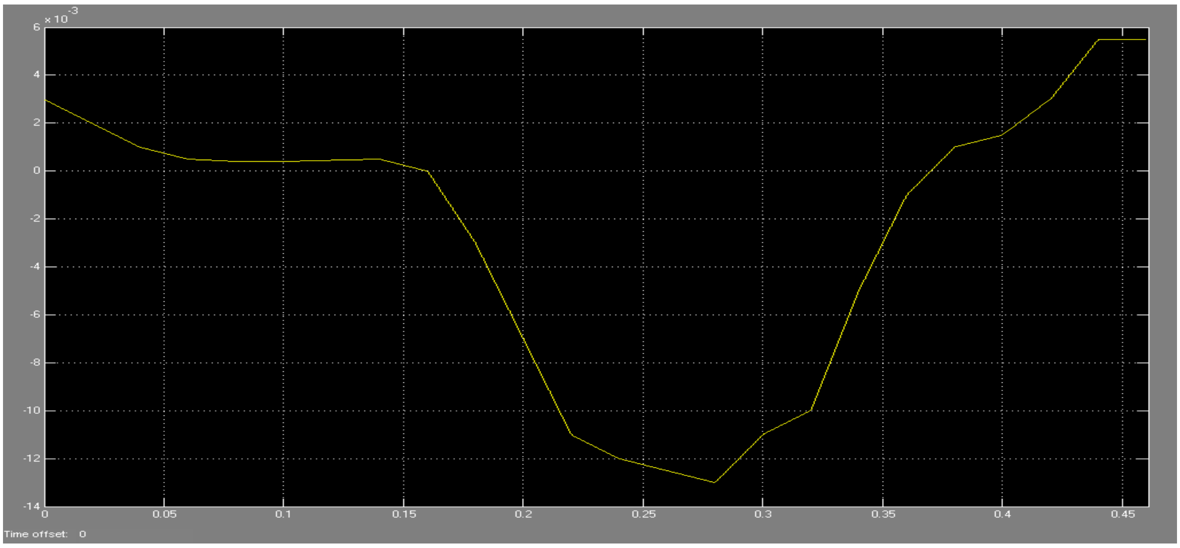

Fig13: Voltage ratio with the control of LPC & PV.

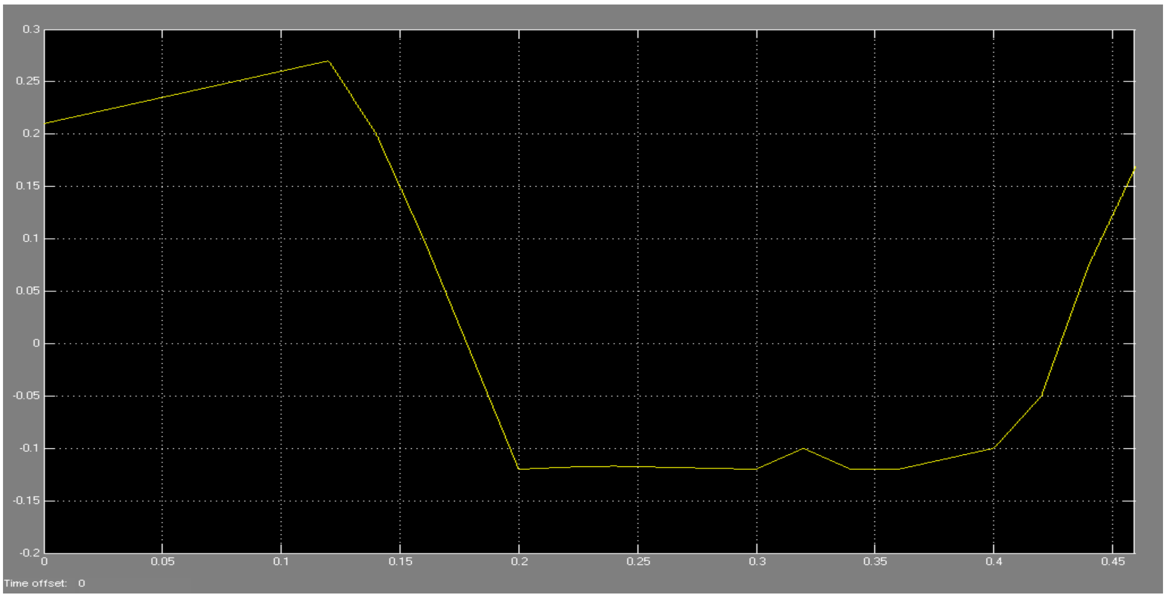

Fig 14: phase shift with control of LPC&PV.

Power load profile of two feeder after using both LPC and PV system as show in fig.11 and fig 12 it shows the real and reactive power after using the LPC and PV system, the differences of real and reactive power between feeders MF65and MU67 have been reduced from 1689KW/1589KVAR after implementing LPC and PV system and both of fig13 and fig14 as show voltage ratio and phase shift.

Distribution Feeder Loss Analysis

To investigate the effectiveness of LPC for the reduction of system power loss by loading balance, a three-phase power flow analysis is performed for both feeders MF65 and MU67 by considering the daily feeder power loading profiles before and after loading balance. Also, the loss incurred in LPC is assumed to be 1% of the power transfer by the LPC which has been included in the system loss analysis for each study hour. For the test distribution system with PV system, Fig. 15 shows the system power loss as percentages of feeder loading. Without applying the LPC for loading balance, the feeder power loss varies from 1.2% of the feeder loading during the light load period to 3.3% during the peak load period. The power loss over the daily period is reduced from 3457 kWh (2.8%) to 2970 kWh (2.3%) after loading balance by LPC. The system power loss reduction has therefore been obtained after implementing the LPC for loading balance.

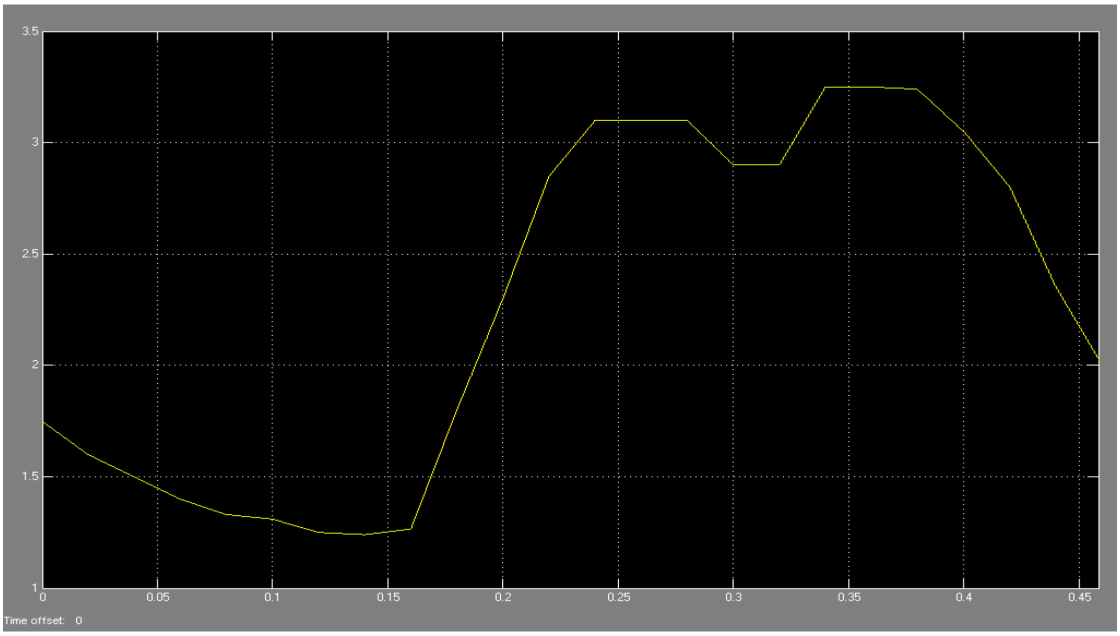

Fig 15: Percentage of system power loss with PV system (w\o LPC).

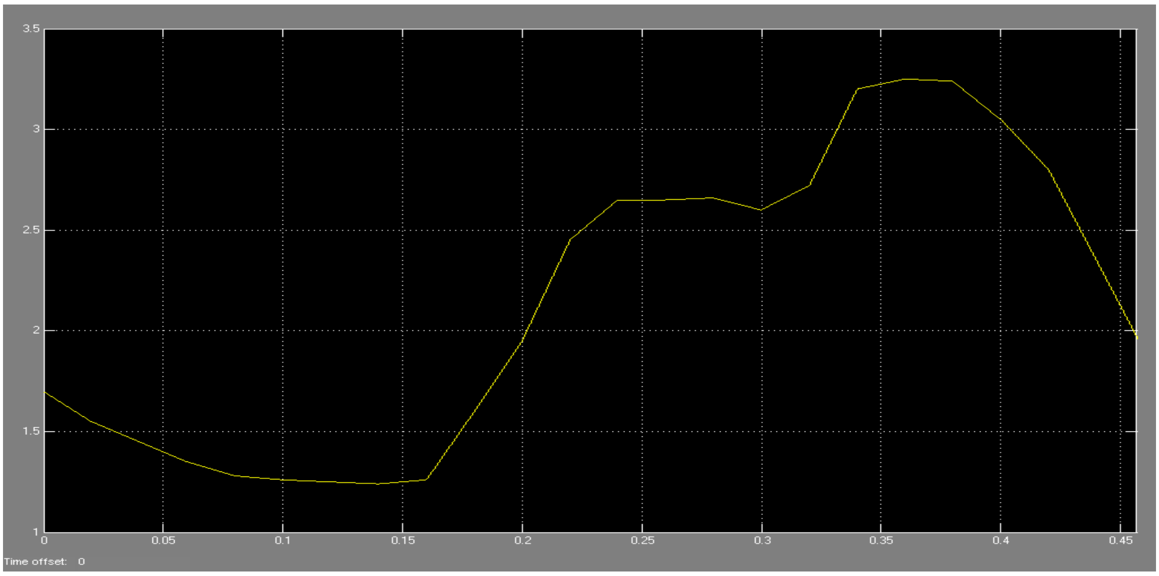

Fig 16: percentage of system power loss applying the LPC&PV.

VI. Conclusions

This study evaluates a power electronics-based loop power controller to replace the open-tie switch for the control of real power and reactive power transfer between distribution feeders to achieve loading balance of distribution system. The voltage ratio and phase shift adjusted by LPC are derived according to mismatches of real power and reactive power loadings between test feeders for each study hour. To demonstrate the effectiveness of LPC for the enhancement of loading balance, a Taipower distribution system consisting of two feeders with a large-scale PV system has been selected for computer simulation. The power loadings of the study feeders and the PV power generation have been recorded. By applying the control algorithm of LPC to adjust the voltage ratio and phase shift between both feeders, the proper amount of real power and reactive power can be transferred from the heavily loading feeder to the lightly loading feeder for each study hour. According to the computer simulation, it is concluded that the loading balance of distribution systems with intermittent PV power generation can be obtained effectively by the implementation of LPC to achieve adaptive control of load transfer between distribution feeders. The power loss reduction of test feeders after loading balance by LPC has also been derived in this paper.

REFERENCES

[1] J.Bebic,R.Walling, K.O'Brien, andB.Kroposki,"The sun alsorises," IEEE Power Energy Mag., vol. 7, no. 3, pp. 45–54, May./Jun. 2009.
[2] T. Key, "Finding a bright spot," IEEE Power Energy Mag., vol. 7, no. 3, pp. 34–44, May./Jun. 2009.
[3] Y.ZhuandK.Tomsovic, "Adaptive power flow method for distribution systems with dispersed generation," IEEE Trans. Power Del., vol. 17, no. 3, pp. 822–827, Jul. 2002.
[4] 2008 Report of Long-Term Load Forecasting and Energy Development, Bureau of Energy, Ministry of Economic Affairs, Taiwan, Dec. 2008.
[5] N. Okada, "A method to determine the distributed control setting of looping devices for active distribution systems," in Proc. 2009 IEEE Bucharest Power Tech (POWERTECH), Bucharest, Romania, Jun. 2009, pp. 1–6.
[6] B. Singh and J. Solanki, "A comparison of control algorithms for DSTATCOM," IEEE Trans. Ind. Electron., vol. 56, no. 7, pp. 2738–2745, Jul. 2009.
[7] S. A. Farouji, E. Bakhshizadeh, R. Kazemzadeh, and R. Ghazi, "The static var compensator equations development for loading balance at desired power factor based on load admittance parameters and instantaneous voltage and current values ,"in Proc.2009 Int. Conf. Elect.Power Energy Conversion Syst., Sharjah, United Arab Emirates, Nov. 10–12, 2009, pp. 1–6.
[8] N. Rugthaicharoencheep and S. Sirisumrannukul, "Feeder reconfiguration with dispatch able distributed generators in distribution system by tabu search," in Proc. 2009 44th Int. Universities Power Eng. Conf. (UPEC 1009), Glasgow, U.K., Sep. 1–4, 2009, pp. 1–5.
[9] V. V. K. Reddy and M. Sydulu, "A heuristic-expert based approach for reconfiguration of distribution systems," in Proc. 2007 IEEE Power Eng. Soc. General Meeting, Tampa, FL, Jun. 24–28, 2007, pp. 1–4.
[10] C. H. Lin, "Distribution network reconfiguration for loading balance with a coloured petri net algorithm," Proc. Inst. Elect. Eng., Gen., Transm., Distrib., vol. 150, no. 3, pp. 317–324, May 2003.

[11] N. Okada, M. Takasaki, H. Sakai, and S. Katoh, "Development of a 6.6 kv–1 MVA transformerless loop balance controller," in Proc. IEEE 38thAnnu. Power Electron.Specialists Conf.,Orlando, FL,Jun.17–21, 2007, pp. 1087–1091.

[12] N. Okada, "Verification of control method for a loop distribution system using loop power flow controller," in Proc. 2006 IEEE PES Power Syst. Conf. Expo., Atlanta, GA, Oct./Nov. 2006, pp. 2116–2123.

[13] N.Okada,H. Kobayashi, K.Takigawa, M.Ichikawa,and K.Kurokawa, "Loop power flow control and voltage characteristics of distribution system for distributed generation including PV system," in Proc. 3rd World Conf. Photovoltaic Energy Conversion, Osaka, Japan, May 12–16, 2003, pp. 2284–2287.

[14] N. Okada, M. Takasaki, J. Narushima, R. Miyagawa, and S. Katoh, "Series connection of snubberless igbts for 6.6 kv transformerless con- verters," in Proc. 2007 Power Conversion Conf., Nagoya, Japan, Apr. 2007.

[15] G. L. Ockwell, "Implementation of network reconfiguration for Taiwan power company," in Proc. 2003 IEEE Power Eng. Soc. General Meeting, Toronto, ON, Canada, Jul. 2003.

Husam Saad Abdulla ,1981,Libya,Sebha, Master of Technology in Electrical Engineering (Power System) , SHIATS, Allahabad , UP,India

Dr. Surya Prakash Belongs to Allahabad, DOB is 01.05.1971, Received his Bachelor of Engineering degree from The Institution of Engineers (India) in 2003, He obtained his M.Tech. In Electrical Engg. (Power System) from KNIT, Sultanpur. UP-India in 2009. Presently he is Pursuing Ph. D in Electrical Engg. (Power System). SSET, SHIATS (Formerly Allahabad Agriculture Institute, Allahabad-India). His field of interest includes power system operation & control, Artificial Intelligent control.