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PHOTOVOLTAIC BASED BALANCING LOAD DISTRIBUTION FEEDERS USING LOOP POWER CONTROLLERS

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Abstract— Balancing load of distribution feeders is significant for falling of power loss and mitigating power flow. As the loop power controller is implanting for the active power and reactive power flows by change in voltage ratio and phase shift. So that the balancing of the load distribution feeders can be achieved. However it can include photovoltaic power producing in feeder balancing load, as a Taipower distribution feeder consisting of two feeders with large amount of photovoltaic equipment considered. The balancing load can be determine in distribution feeders with photovoltaic set up by using the loop power controllers as the changing of solar energy and power loading of feeders. With implanting the control algorithm in MATLAB for loop power controller by changing the voltage ratio and phase shift connecting to the feeder the proper amount of active power and reactive power can be change from the heavily loading feeder to the lightly loading feeder. When system power loss decreases, Photovoltaic balancing the load for loop power controller has been investigated.

I.INTRODUCTION

Recycling energy resources such as wind and solar power are more and more included in power system development and process to reach carbon dioxide emission decrease the utilization of fossil fuels by predictable thermal power production. Saturation of wind power produced and photovoltaic power produced into distribution systems is likely to increase, which increase the amount of power system impact by the alternating power production in distribution generation[1]-[3]. Evaluate to important of wind power and predictable bulk generation, the production cost of a photovoltaic system is moderately higher. The type of Recycling energy source such as photovoltaic, which have been directly converts the sunlight in to electrical power, lacking help of mechanical or thermal inter link. photovoltaic are more often than not connected together to make photovoltaic modules, consisting of 72 photovoltaic, which produces a direct current voltage between 23 Volt to 45 Volt and a normal maximum power of 160 Watt, which depending on temperature and solar irradiation. Now days many countries are offer economic subsidies to support clientele to set up photovoltaic systems. To reach the target of 1000 MW photovoltaic set up capacity by 2025, the Taiwan government has begin a supporting program to sponsor 50% of the photovoltaic setting up cost and has improved the selling price of photovoltaic generation to 40z/kWh. It is serious distribution systems to balancing the load of main transformers and feeders to stop the system overloading problem during the summer time due to the heavy use of air conditioners and etc. balancing the load is also significant for both outages and service return after fault is separated to achieve load changes between distribution feeders. To improved distribution system, balancing the load is made by the best reconfiguration of distribution system as the load demand can be uniformly allocated among feeders and main transformers in substations. By the distribution system function, balancing the load have reach by changing the open/closed switches of distribution feeders so that partial point of heavily loaded feeders can be change to relatively lightly loaded feeders. As the feeder loading will changes from instance to instance, which will make it very complicated to reach the preferred of balancing the load with the system arrangement in the system with adding the Recycling distributed generation such as wind power and photovoltaic power being set up in distribution feeders, balancing the load of distribution systems becomes more interesting due to the addition of alternating power production. By using the power electronics based on flexible alternating current transmission system has been proven very effective for calculating the load changing connecting feeders to reach balancing load. Significant hard work has been donned in the previous papers to balancing the load of distribution systems [4]. The distribution static compensator was measured of loading unbalance caused by stochastic load require in distribution. The control algorithm for static var compensation has been implemented for balancing the load at anytime of power factor. Fuzzy multi objective have to reach the on/off patterns of tie switches to reach feeder balancing the load in distribution systems with distributed generators. As the distribution system consisting of huge amount of capacity of photovoltaic setting up, the feeder loading will change significantly because the powers add by photovoltaic production is change with the intensity of solar energy. As the load between feeders with an open-tie switch must be change according to photovoltaic power production. Due to the alternating power production by photovoltaic systems, it becomes very complicated to reach balancing the load with usual display reconfiguration methods by changing the line switches. With have been developments the power electronics, the end-to-end converters can be practical to change the open-tie switch for improved of active power and reactive power load by change the voltage ratio and phase shift of two feeders according to the power unbalance at any time moment. the distribution system with high penetration of Recycling energy sources, voltage profile and balancing the load have to be improved by power replace capacity among the feeders [5]. In This loop power controller open-tie switch so that balancing the load of distribution feeders can be reach by power flow in a more active manner. A transformer less converter with endless insulated gate bipolar transistor is implemented to use of loop power controller and active-gate-control. The active-gate-control can balance the collector voltage of insulated gate bipolar transistor is coupled in series and permit the relationship directly to distribution feeders with a high alternating current voltage output. Loop power controller can decrease the voltage variation and system power loss by enhancing reactive power. In this way we considering the three-phase balancing the load flow condition is consider for both distribution feeders to carry out the load transfer by loop power controller

II. PHOTOVOLTAIC TECHNOLOGY

Photovoltaic is the technology and research the devices which have been directly convert sunlight into electricity with semiconductors that show the photovoltaic effect. Photovoltaic effect that creation of voltage in a material exposure to electromagnetic radiation. The solar cell is the primary block of the photovoltaic. And it is made of semiconductor devices, such as silicon. The property of semiconductors with has been useful in conductivity it has been simply modified by implanting the crystal lattice. For time been, the production of a photovoltaic solar cell, silicon, which has the four valence electrons, it add to its conductivity. On the side of the cell, the impurity, which has the phosphorus atoms with five valence electrons contribute weakly bound valence electrons to the silicon material, generate excess negative charge. Atoms with have been boron with three valence electrons generate a greater affinity than silicon to draw electrons [6]. Because the p-type silicon is in open contact with the n-type silicon a p-n connection is recognized and a diffusion of electrons occurs from the region of large electron attentiveness into the region of low electron absorption. When the electrons diffuse across the p-n connection, they recombine with holes on the p-type. As, the diffusion of carrier not occur for an indefinite time, because the variation of charge instantaneously on either sides of the junction originate an electric field. This electric field which has been forms a diode that allows the current to flow in single direction. Ohmic metal-semiconductor links to both the n-type and p-type of the solar cell, and the electrodes are set to be linked to an external load. When the photons of light fall on the cell, they vary energy to the charge carriers. The electric field connection separates to the photo-generated positive charge carrier from their negative equivalent. In this manner we generates electrical current is extract once the circuit is closed on an external load.

III. BALANCING THE LOAD POWER

In general, balancing the load is been process to keep the outputs in limits and the system load also in limits or as the system necessities. Balancing the load is used in many fields such as power, computer, internet, telecommunication substation, power generation and ect. In this method we find the balancing the load in electrical field. The load or power utilization is changes every day and time to time. However it is important to handle the change in loads to make sure that system is not overloaded or less loaded. In urban areas, the loads require is very huge and load very drastic, power plants generally utilize the automatic production control. Automatic generation controls producing the power at the power station, depending upon the load change in that particular area [7]. As we consider if load utilization in area is 100 loads and due to weather and some other reason it goes to 200 loads, the area which is using twice loads than that of the regular usage. So the automatic generation controls that producing the power which required the power to that area. But automatic generation control utilization is usually very costly. So for the areas with small power plants, balancing the load is usually quite than the automatic generation control. Balancing the load provides substations to meet load requirement. Balancing the load of power is complete by open/close tie-switches in the distribution feeders. Overloading of system is controlled by change the load from heavily loaded feeders to the less loaded feeders. Reconfiguring system is the main techniques of balancing the load. It permits smoothening the load required by distribution, decrease the feeder losses and better system reliability balancing the load is include at the power distribution. The some action will be taken during overloading condition is to balance the load from over loaded area to the less loaded areas. The change is done through open/closed switches. In this way we have been designed the balancing the load system for three phase assuming that the total load remains constant.

IV. LOOP POWER CONTROLLING MODEL OF DISTRIBUTION SYSTEM

The concept of the loop or mesh distribution system is implementing in the loop power controller as we suggest in this. To actualize group and release scheme by the loop or mesh system for the function of open access to the distributed power deliver. System responds flexibly for difference load connecting feeders, and makes successful use of distribution systems [8] .Loop power distribution system is provided lacking of altering existing systems such as the protection system, excluding for the loop points. Loop power controller is able to take most favorable control for distribution systems in the points of dropping voltage rise, voltage variation and loss is minimum for power flow and so on, with achievement of state of distribution systems. Adapting to the area which have been not using the communication system, from the points of view at the power quality for the change phenomena, the distributed control is implanting the local voltage in order achieve the loop power controller.

4A. VSI is using in loop power flow controller

In this way a loop power controller which has been consists of a series inductor and a series-connected voltage source inverter. The system relationship is presented in Fig.1. In Fig.1, X_s is a series inductor which has been placed with the inverter. Inconsistent v_s means the immediate output voltage of the inverter and v_{Xs} means the immediate voltage across the series inductor [9]. The direct current voltage of the inverter is handled by the two capacitors because the inverters have the reactive power only. The two series capacitors C_1 and C_2 give a neutral point, and then the inverter can be in charge of its output voltage in each phase,

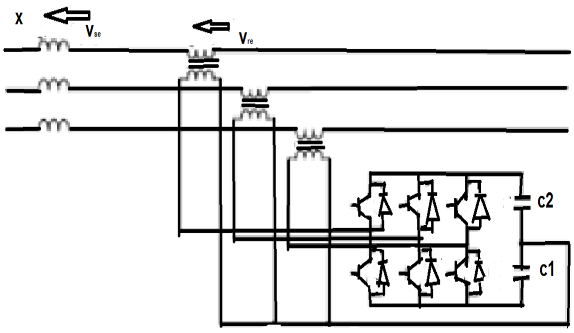

Fig. 1 loop power flow controller model configuration.

The main objective of loop power controller is too implemented in the power flow and fault current limitation. The loop power controller is usually implemented for power flow control connected two distribution lines. When system error occurs on the distribution feeder, the loop power controller decrease a huge amount current witch caused by the fault and prevents critical variation from the line to the other distribution feeder [10]. From the points of view, the loop power controller is connects to the receiving ends of two distribution feeder. In this way, a distribution system shown in Fig. 2 is used for planning and simulation studies. $\dot{V}_{t1}$ and $\dot{V}_{t2}$ shows the sending end voltage of every distribution line. R represents the line resistance, and X is a line reactance. For the ease, the load of the distribution line is considered as a resistance R_L, and it is achieve at the end of the distribution feeder. The circuits constants are go with by a suffix number, which denote the distribution line.

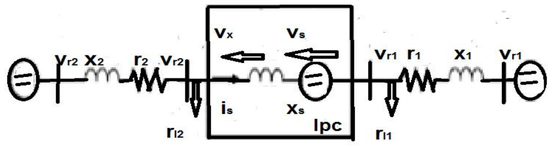

Fig. 2 loop power flow controller model with distribution system.

4B. Control Algorithm of loop power controller To determine the Loop power controller the voltage ratio and phase shift of the control of load change, the corresponding circuit of Loop power controller is planned by taking into account of the branch impedances of distribution feeders for the simulation of feeder balancing the load [13]. Fig. 3 shows the common process to determine the Loop power controller to control algorithm to improve balancing the load of distribution feeders. In this we have been study, the Loop power controller is consider as the collection of tap changer and phase shifter with a circuit

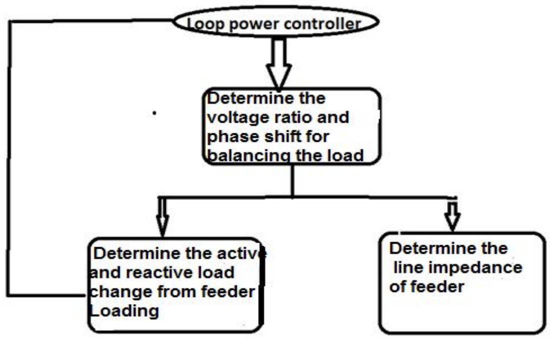

Fig. 3 Algorithm flow chart of loop power control

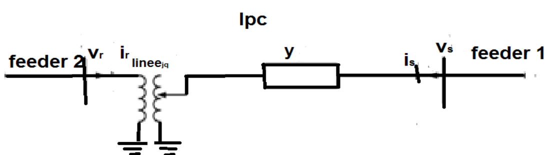

Fig. 4 loop power controller model

in Fig. 4. By change the voltage ratio and phase shift connecting both sides of the Loop power controller to the branch impedance and loading unbalance of distribution feeders, to achieve the active and reactive power change through the Loop power controller can be restricted to achieve the balancing the load [14]. The corresponding circuit model can be representing as a model transformer with turn ratio of $1{:}ne^{j\emptyset}$ and a series admittance y. The mathematical model of Loop power controller as show in equation in (1) to show the connection between the node adding currents and voltages

$$\begin{bmatrix} I_s \\ I_r \end{bmatrix} = \begin{bmatrix} |n|^2 y & -ny \\ -ny & y \end{bmatrix} \begin{bmatrix} V_s \\ V_r \end{bmatrix} \quad \text{------------ (1)}$$

Where $n = n^{j\emptyset}$

To modified the formula to achieve the voltage ratio and phase shift of Loop power controller [15]. In this way we have planned to modify corresponding circuit with needy on currents source and as shown in Fig. 5. Here, the needy current sources are repeated according to the change of turn ratio and phase shift during the iteration method. To determine the adding currents due to the varying of voltage ratio by Loop power controller the node currents are shown by considering it zero phase shifts as follows:

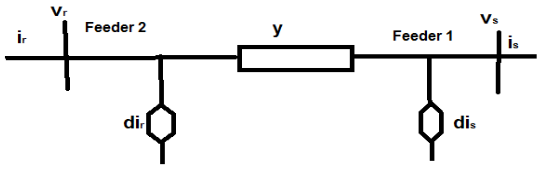

Fig. 5 Equivalent circuit model of loop power controller.

$$I_s = n^2 yV_s \text{-ny} V_r$$

$$= (n^2\text{-}1)\text{y}v_s + (1\text{-n})\text{y}v_r + \text{y}(v_s\text{-}v_r) \quad \text{---------(2)}$$

$$I_r = \text{-ny}v_s + yV_r$$

$$=(n^2\text{-}1)\text{y}V_s + y(V_r - V_s \quad \text{----------(3)}$$

$$di_s' = -(n^2-1)yV_s - (1-n)yV_r \text{---------- (4)}$$

$$di_s' = -(1-n)yV_s \quad \text{------- (5)}$$

To determined the adding current due to the varying of phase shift by Loop power controller. the node currents are shown by considering a eternal voltage ratio of 1.0 as follows The corresponding adding currents can be determined so, the corresponding currents due to the vary of both voltage ratio and phase shift by Loop power controller are shown as follows

$$di_s' = -\left(1 - e^{-j\emptyset}\right)yV_r \quad \text{--------- (6)}$$

$$di_r'' = -\left(1 - e^{j\emptyset}\right)yV_s \quad \text{-------- (7)}$$

$$\begin{bmatrix} di_s \\ di_r \end{bmatrix} = \begin{bmatrix} (1-n^2)y & (n + e^{-j\emptyset} - 2)y \\ (n-1)y & (n + e^{j\emptyset} - 2)y \end{bmatrix} \begin{bmatrix} V_s \\ v_r \end{bmatrix} \quad \text{-- (8)}$$

By this manner, the system impedance matrix remains constant during the iteration method to determine the voltage ratio and phase shift of Loop power controller. To demonstrate the planned control algorithm for Loop power controller to reach feeder balancing the load, let as assume the two sample radial feeders linked with a Loop power controller [11]. The preferred active and reactive power flows from end to end of Loop power controller for feeder balancing the load as If the branch impedances of Feeder 1 and Feeder 2 are (R_1, X_1) and (R_2, X_2) , correspondingly, the overall impedance of two feeders In arrange to achieve the Loop power controller control approach to have the suitable load change connecting the both feeders for balancing the load , the terminal voltage V_{L1} at the primary side of Loop power controller is implicit to have a permanent value of 1.0∟0°. The terminal voltage at the secondary side of Loop power controller is determined.

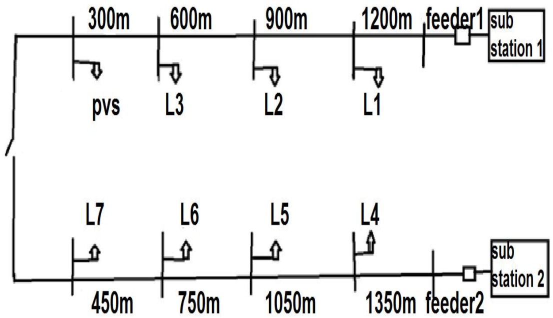

Fig. 6 distribution feeders of tai power is used in mat lab simulation.

$$\Delta v = |V_{12}^1|\text{-}1.0 \quad \text{--------- (9)}$$

$$\Delta\emptyset = Tan^{-1}\frac{P_{lpc}X_t - Q_{lpc}R_t}{1P_{lpc}R_t + Q_{lpc}X_t} \quad \text{------ (10)}$$

V. STUDY OF TIEPOWER DISTRIBUTION WITH PHOTOVOLTAIC AND LOOP POWER CONTROLLER

To show the importance of the planned of Loop power controller for balancing the load of distribution feeders with photovoltaic capacity, a Tai power distribution system has been used in mat lab simulation as shown in Fig. 6. A significant photovoltaic system with 8844 pieces of solar plates has been set up on the top with full capacity of 1027 kWp. Feeder1 is supplied by substation1 to serve Kaohsiung Stadium and other low-voltage clientele. The feeder is linked to Feeder2 with an open line switch so that any change occurred in the load can be obtained for service return during fault time. With such a huge photovoltaic system being set up, it is likely that overall annual photovoltaic electricity producing of 1.37 GWh can be obtained [11]-[12]. So that the everyday power produced by photovoltaic system has been noted by the Supervisory Control and Data Acquisition system as shown in Fig. 8. It is establish that the photovoltaic power production is improved with solar irradiation. The huge amount of power produced was 768 kWh at 12 PM, and the total amount energy of 6702 kWh has been reached for June 30, 2009.

Fig. 9 gives as the everyday load profiles of active and reactive power balancing the loading of Feeders1 and 2 not including the power add by the photovoltaic system. The heavy loading of Feeder1 was obtained is 3724 kW/1232 kVAR at 8 PM and the heavy loading of Feeder2 was obtained is 4483 kW/1485 kVAR at 2 PM. Feeder1 serve the suburban area with clientele requires most of the power during night hours when people live at home with large amount air conditioner loading. Feeder2, though, serve the business area with clientele observed most of power require during day hours business hours. Fig. 10 shows the decreasing of active power producing of Feeder1 during day hours after adding photovoltaic power produced in the distribution system.

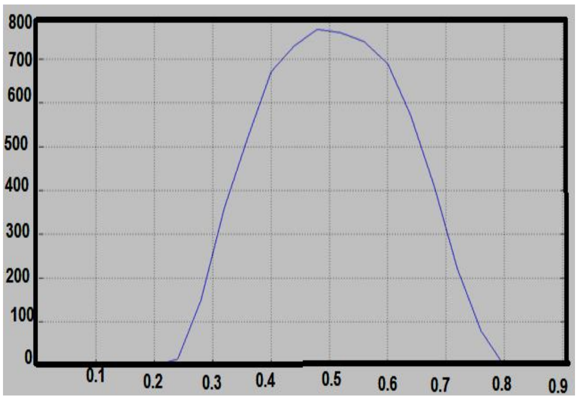

Fig. 7 photovoltaic power generation taipower feeder.

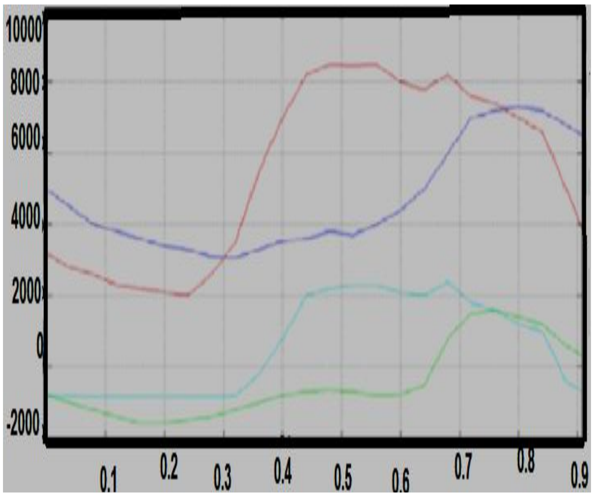

Fig.8 balancing the load of Power profiles of Feeder1 and 2 (without photovoltaic system).

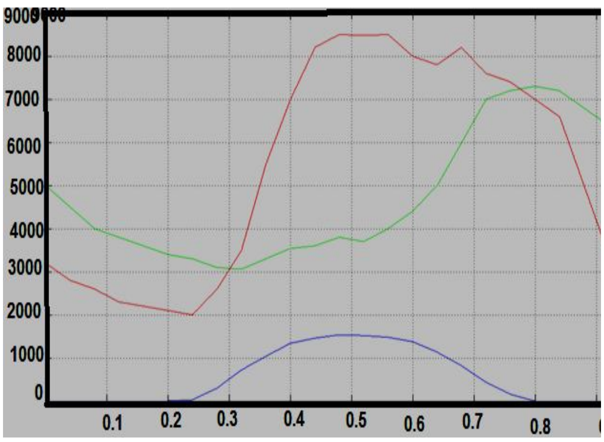

Fig.9 balancing the load of Power profiles of Feeder1and2 (with photovoltaic system)

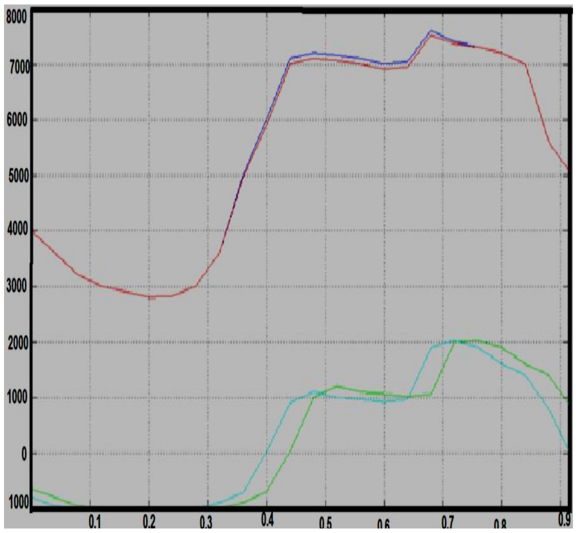

Fig.10 balancing the load of both feeders with the control of LPC (w/o photovoltaic system)

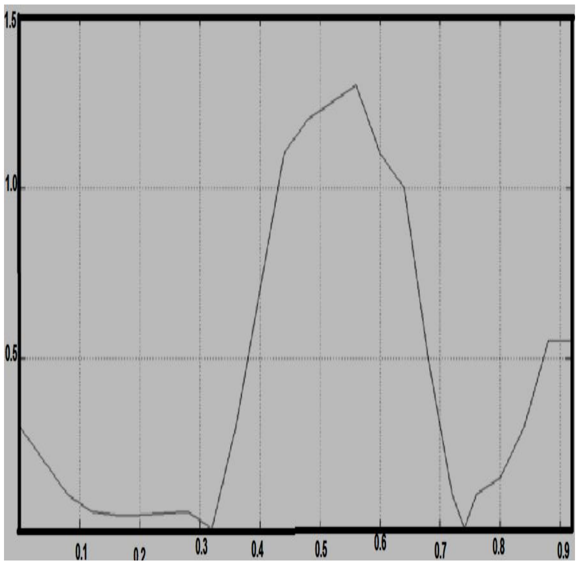

Fig.11 power change by Lpc in the Voltage ratio and phase shift (without the PV system)

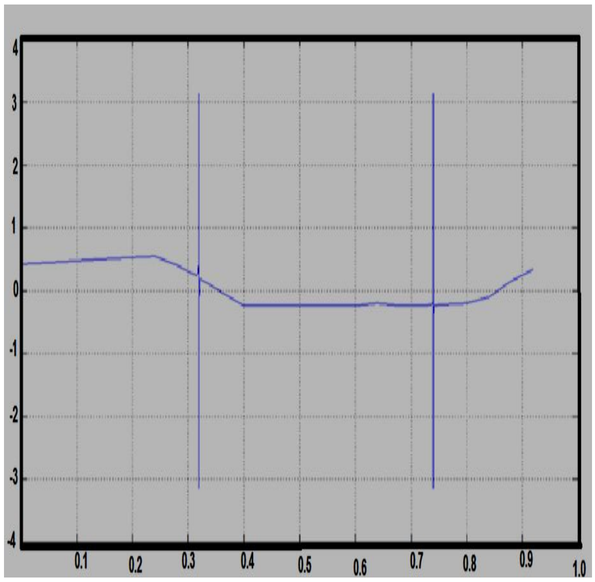

Fig.12 power change by Lpc in the Voltage ratio and phase shift (without the PV system)

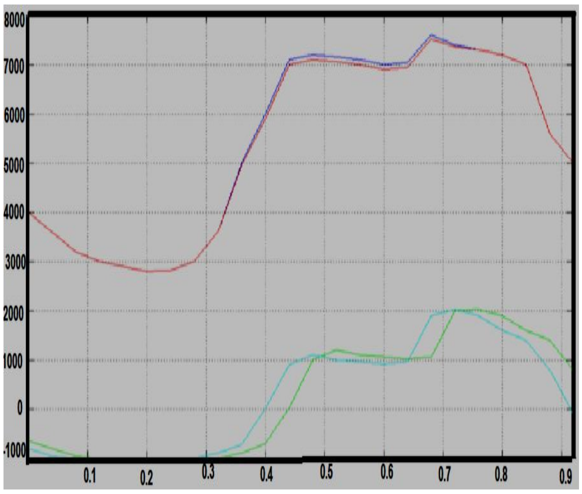

Fig.13 Balancing the load of both feeders with the control of LPC (with photovoltaic system)

5A. Balancing the load of Distribution Feeder with Loop Power Controller

By change of client loading profiles and the alternating producing of photovoltaic, by a Loop power controller be in change of algorithm is to determined the change in voltage ratio and phase shift connecting the both feeders according to the feeder loading and photovoltaic production have been verified for every time. To show the success of Loop power controller for system balancing the load, by the Loop power controller is consider to be replacing the open-tie switch connecting the Feeders1 and 2as shown in Fig. 6. After increasing the balancing the load by Loop power controller for the distribution system without implanting the photovoltaic, Fig. 11 represent the active power and reactive power profiles of both feeders. By comparing to Fig. 9, it is observed that the balancing the load of the modify system is considerably increased by Loop power controller to reach good power change between both the feeders. The variation of active power and reactive power loadings connecting the Feeders1 and 2 at 3PM have been analyzed from 1864 kW/1715 Kvar to 170 kW/71kVAR after including the Loop power controller for power flow .

Fig. 12 and 13 shows the equivalent voltage ratio and phase shift for every hour, which are determined in for Loop power controller to reach the load change connecting the both feeders. At 3PM, by phase shift is useful for active power change of 1012 kW from feeder2 to 1 where as the voltage ratio of 0.013 p.u. is implanted for reactive power change of 890 kVAR from 2 to 1. In additional, the a phase shift of 0.27 is used for real power change of 450 kW from feeder1 to 2 at 6 AM, and the voltage ratio of 0.001 p.u. is implanted for reactive power change of 190 kVAR from 2 to 1.

By observing the Fig. 12 and 13, the voltage ratio of Loop power controller remains constant because the photovoltaic does not affects reactive power. However, the phase shift of Loop power controller essential for active power balancing is improved during the day hours when the active power produced by the photovoltaic is added. For occasion, a better phase shift is implemented for active power change of 897 kW from feeder2 to 1 at 3 PM. By the been in charge of Loop power controller. The balancing the load of feeders as one with the photovoltaic power production has been achieve as represented in Fig. 14. By observing Fig. 10, they is a difference between active power and reactive power balancing the load connecting the Feeder1 and Feeder2 at 3 PM are decrease from 2574kW/1727 kVAR to 191kW/79 kVAR after balancing the load .

5B. Distribution Feeder Loss Analysis

To examine the success of Loop power controller for the decrease of power loss by balancing the load , a three-phase power flow have been implemented for both feeders1 and 2 by implementing the daily feeder power loading profiles before and after balancing the load. Also, the loss in current in Loop power controller is consider to be 1% of the power change by the Loop power controller which has been implemented in the system loss for each hour

VI. CONCLUSIONS

In this paper the power electronics-based on loop power controller to change the open-tie switch for the manage of active power and reactive power connecting to distribution feeders to reach balancing load of distribution system has been investigated. The voltage ratio and phase shift changing by Loop power controller are determined the difference of active power and reactive power load connecting the feeders for each hour. To determine the success of Loop power controller for the improvement of balancing load, a Taipower distribution system consisting of two feeders with a huge amount of photovoltaic has been implanted for MATLAB simulation. The power loadings of the feeders and the photovoltaic power produced have been observed. By implementing the control algorithm of Loop power controller to changing the voltage ratio and phase shift connecting the both feeders, the good amount of active power and reactive power can be changed from the heavily loading feeder to the lightly loading feeder for each hour. From MATLAB simulation results, it is concluded that the balancing the load of distribution systems with alternating photovoltaic power produced can be achieve successfully by the implementation of Loop power controller to determined the control of load changing connecting the distribution feeders. The power loss decrease of feeders after implementing balancing load by Loop power controller has been determined.

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