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Photovoltaic Based Loading Balance of Distribution Feeders With Loop Power Controllers in Distribution Feeders

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Abstract:*Balancing load of distribution feeders is significant for falling of power loss and mitigating power flow. As theloop 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 producingin feeder balancing load, as a Taipower distribution feeder consisting of two feeders with large amount of photovoltaicequipment considered. The balancing load can be determine in distribution feeders with photovoltaic set up by using the looppower controllers as the changing of solar energy and power loading of feeders. Daily loading unbalance is set by analyzing PV power generation recorded by the system and by constructing daily power load profiles supported distribution automation system (DAS) data. The load transfer needed to realize loading balance and therefore the line impedance of distribution feeders ar used to derive the voltage, ratio and phase shift of the LPC. Computer simulations indicated that loading balance is achieved in distribution feeders with massive PV system installation by exploitation loop power controllers according to the variation of solar energy and loading of study feeders. The system power loss reduction ensuing from feeder loading balance by LPC is additionally investigated during this paper.*

Keywords-leakage current, parasitic capacitance, switching converter.

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 reconfigurationof distribution system as the load demand can beuniformly allocated among feeders and maintransformers in substations. By the distributionsystem function, balancing the load have reach bychanging the open/closed switches of distributionfeeders so that partial point of heavily loaded feederscan be change to relatively lightly loaded feeders. Asthe feeder loading will changes from instance toinstance, which will make it very complicated toreach the preferred of balancing the load with thesystem arrangement in the system with adding theRecycling distributed generation such as wind powerand photovoltaic power being set up in distributionfeeders, balancing the load of distribution systemsbecomes more interesting due to the addition ofalternating power production. By using the powerelectronics based on flexible alternating currenttransmission system has been proven very effectivefor calculating the load changing connecting feedersto reach balancing load. Significant hard work hasbeen donned in the previous papers to balancing theload of distribution systems [4]. The distributionstatic compensator was measured of loadingunbalance caused by stochastic load require indistribution. The control algorithm for static varcompensation has been implemented for balancingthe load at anytime of power factor. Fuzzy multiobjective 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 theload with usual display reconfiguration methods bychanging the line switches. With have beendevelopments the power electronics, the end-to-endconverters can be practical to change the open-tieswitch for improved of active power and reactivepower load by change the voltage ratio and phaseshift of two feeders according to the power unbalanceat any time moment. the distribution system with highpenetration of Recycling energy sources, voltageprofile and balancing the load have to be improvedby power replace capacity among the feeders [5]. InThis loop power controller open-tie switch so thatbalancing the load of distribution feeders can be reachby power flow in a more active manner.

II. DISTRIBUTION AUTOMATIONSYSTEM WITH LOOP POWER CONTROLLER

To enhance reliability and operation efficiency of distributionsystems, the fully integrated distribution automation system(DAS) in Fig. 1 has been implemented by Taiwan PowerCompany (Tai power). The DAS consists of a master station(MS) with application software, remote terminal units (RTUs)in the substations, feeder terminal units (FTUs), and automaticline switches along the primary feeders [15]. The distributionfeeders from substations are connected as the open loopconfiguration with one of the automatic line switches beingselected as the open-tie switch. To achieve loading balance ofdistribution feeders for normal operation with variation offeeder loading, the non-interruptible load transfer is executedby closing the open-tie switch and opening one of the normalclose switches. When a fault contingency occurs, the feedercircuit breaker trips, and the over-current fault flags of allupstream FTUs are set due to the large fault current flows.After the MS retrieves all fault flags, the fault location cantherefore be determined according to the combination of faultflags and the network topology. The MS then sends thecommand to open all line switches around the faulted sectionto complete the faults isolation and followed by reclosing thefeeder circuit breaker to restore power service to upstreamcustomers. After verifying the reserve capacity of thesupporting feeder, the open-tie switch is closed to fulfill theservice restoration of down stream customers[6].

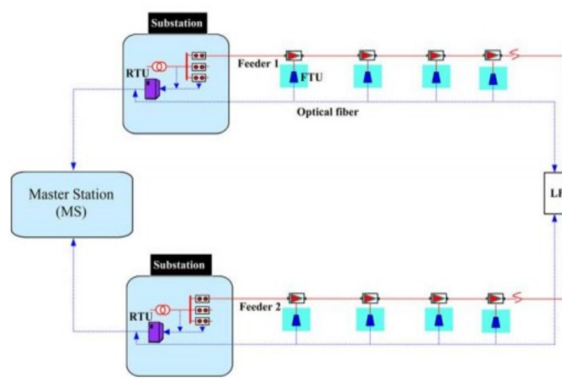


Fig 1 Distribution automation system with loop powercontroller

Although the DAS has been applied for fault restorationeffectively in Tai power, the loading balance is difficult to beperformed for distribution system with large DG facilitybecause too frequently the switching operation is required toaccommodate the dramatic fluctuation of DG generation. Tosolve the problem, Fig. 1 shows how the proposed LPC isapplied to replace the open-tie switch by achieving adaptivepower flow control for load transfer.

In DAS fault restoration effectively in taipower, but balance of loading is difficult in distributionsystem because the switching operation is required too frequently, to overcome the problem we are proposingthe LPC, it is applied to replace open tie switch by adaptive power flow control for load transfer. Theadvantages of LPC in distribution feeder pair, 1) reduce the voltage fluctuations with fast compensate thereactive power. 2) The real power and reactive power is controlled.

III. LPC CONTROL MODEL

The LPC control of load transfer to derive voltage ratio and phase shift, the LPC equivalent circuitmodel is proposed by considering the branch impedance of distribution feeder for the simulation of feeder loadbalance. The overall process to derive the LPC control algorithm as shown in fig .2

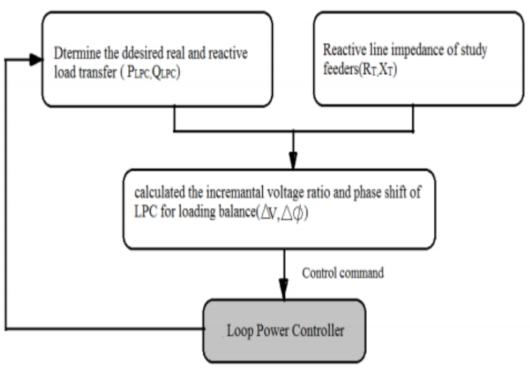


Fig .2 Flowchart of LPC control algorithm.

A. Simulation of feeder loading balance

The circuit model of LPC considers as the combination of phase shifter and tap changer has shownin fig. 3 . By adjusting voltage ratio phase shift between both sides of LPC, according to the branchimpedance and loading unbalance of distribution feeders. LPC can be controlled real power and reactive powerto achieve the load balance. The ideal transformer having the equivalent circuit model with turn ratio of 1:nejØ .

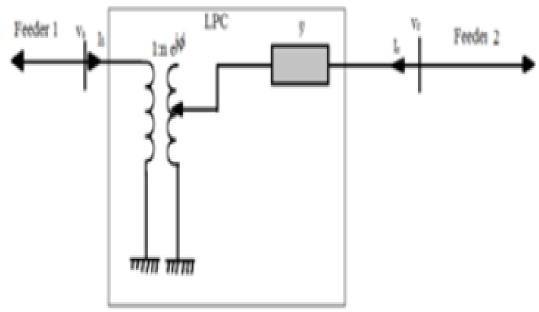


Fig. 3. Circuit model of loop power controller

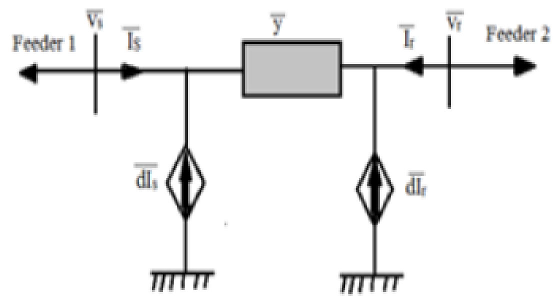


Fig. 4. Modified equivalent circuit model of LPC

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

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

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

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:

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

.........(2)

$$I_r = -n\bar{y}\bar{V}_s + \bar{y}\bar{V}_r$$
$$= (1-n)\bar{y}\bar{V}_s + \bar{y}(\bar{V}_r - \bar{V}_s).$$
……….(3)

The equivalent injection currents are solved as

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

$$dI'_r = -(1-n)\bar{y}\bar{V}_s.$$
…………..(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:

$$I_s = \bar{y}\bar{V}_s - \bar{y}e^{-j\phi}\bar{V}_r$$
$$= (1-e^{-j\phi})\bar{y}\bar{V}_r + \bar{y}(\bar{V}_s - \bar{V}_r)$$ ………….(6)

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

The equivalent injection currents are solved as

$$dI''_s = -(1-e^{-j\phi})\bar{y}\bar{V}_r$$ ………….(8)

$$dI''_r = -(1-e^{j\phi})\bar{y}\bar{V}_s.$$ …………..(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:

$$dI_s = dI'_s + dI''_s$$ ………….(10)

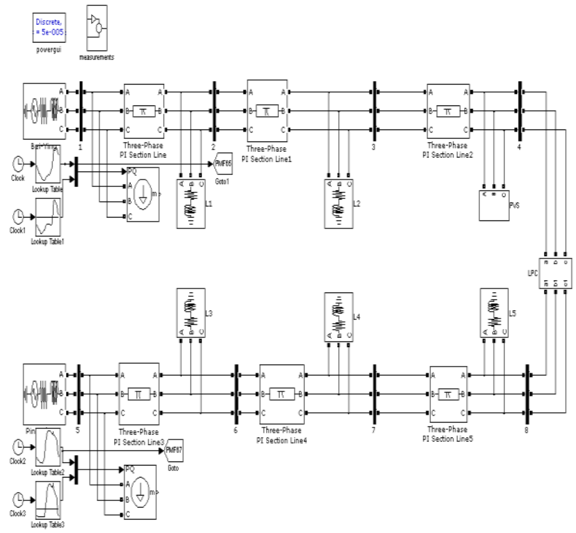
$$dI_r = dI'_r + dI''_r$$ ………….(11)

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

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

IV. SIMULATION RESULTS

The loading balance of distribution feeders to adjust voltage ratio and phase shift between both feeders by using LPC and the injection FC power, the LPC assumed to be installed replacing the open tie switches between feeder.



Fi.g 5 Loading balance without PV

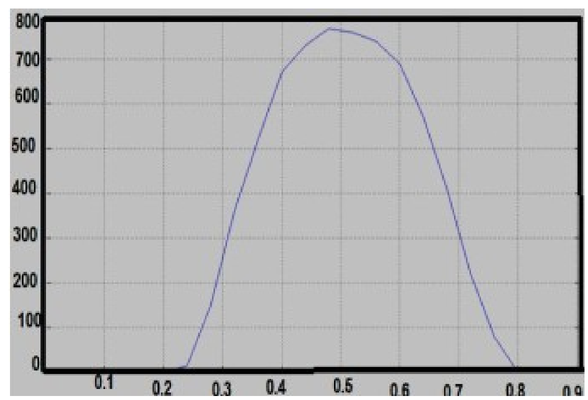


Fig. 6 photovoltaic power generation taipower feed

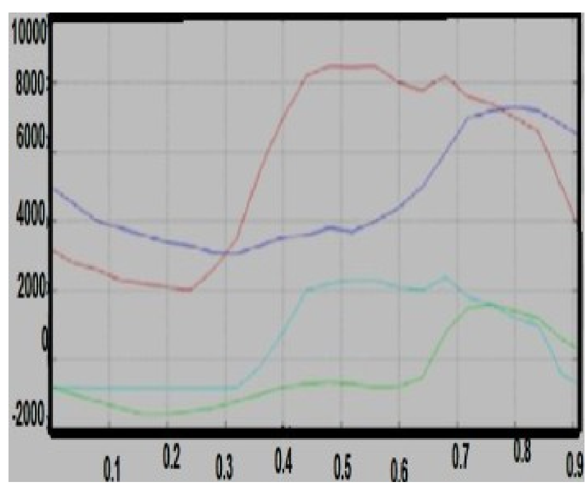


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Fig.7 balancing the load of Power profiles of Feeder1 and 2(without photovoltaic system).

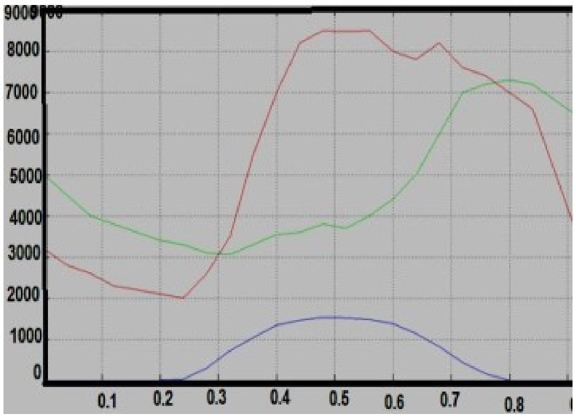

Fig.8 balancing the load of Power profiles of Feeder1and2(with photovoltaic system)

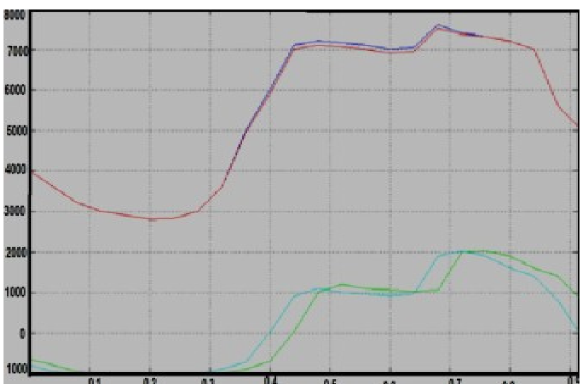

Fig.9 balancing the load of both feeders with the control ofLPC (w/o photovoltaic system)

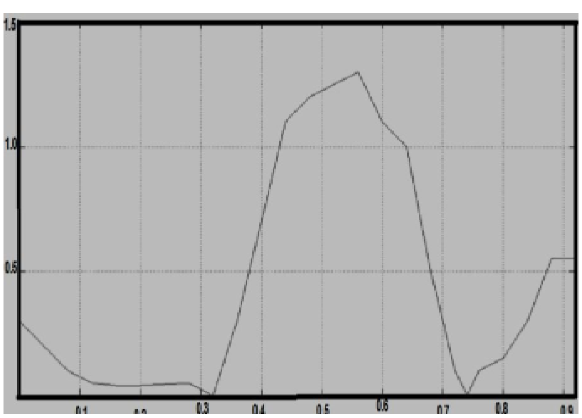

Fig.10 power change by Lpc in the Voltage ratio and phaseshift (without the PV system)

CONCLUSION

In this paper the power electronics-based on looppower controller to change the open-tie switch for themanage of active power and reactive powerconnecting to distribution feeders to reach balancingload of distribution system has been investigated. The voltageratio and phase shift adjusted by LPC are derived according tomismatches of real power and reactive power loadings betweentest feeders for each study hour. To demonstrate theeffectiveness of LPC for the enhancement of loading balance, aTai power distribution system consisting of two feeders with alarge-scale PV system has been selected for computersimulation.

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BIODATA

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