INTERNATIONAL JOURNAL OF RESEARCH
In Advanced Engineering Technologies
Volume 5, Issue 1 SEP 2015

Loading Balance of Distribution Feeders With Loop Power Controllers Considering Fuel Cell Generation

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Abstract- For the operation of distribution systems, loading balance of distribution feeders is important for reducing power loss and mitigating power flow overloading. In this paper, a loop power controller (LPC) is applied for the control of real power and reactive power flows by adjusting voltage ratio and phase shift so that the loading balance of distribution feeders can be obtained. To incorporate fuel cell power generation in feeder loading balance, a Taipower distribution feeder with large fuel cell is selected for computer simulation. Daily loading unbalance is determined by analyzing fuel cell power generation recorded by the SCADA system and by constructing daily power load profiles based on distribution automation system (DAS) data. The load transfer required to achieve loading balance and the line impedance of distribution feeders are used to derive the voltage ratio and phase shift of the LPC. Computer simulations indicated that loading balance can be achieved in distribution feeders with fuel cell system by using loop power controllers according to the variation of solar energy and power loading of study feeders. The system power loss reduction resulting from feeder loading balance by LPC is also investigated in this paper.

Index Terms — Distribution automation system, loop power controller, fuel cell.

I. INTRODUCTION

Environmental-friendly distributed generation systems (DGS) such as fuel cells, wind turbines, hydro turbines or photovoltaic arrays are rapidly increasing around the world because they can meet both the increasing demand of electric power and environmental regulations due to green house gas emission [1]-[8]. Outstanding advances in Power Electronics and energy storage devices for transient backup have accelerated penetration of the DGS into electric power generation plants.

These DGS technologies can be used for various applications to a standalone, a grid-interconnection, a cogeneration, a standby, peak shavings, etc. and have many benefits such as environmental-friendly, modular electric generation, increased reliability, high power quality, uninterruptible power service, cost savings, on-site generation, and expandability, etc.

The fuel cells are electrochemical devices which convert chemical energy directly into electric energy by reaction of hydrogen from the fuel and oxygen from the air without regard to climate conditions unlike hydro or wind turbines and photovoltaic arrays [7]-[18], [25]- [26]. Thus, the fuel cells are one of the most attractive DGS resources for power delivery. However, batteries need to be placed in parallel or series with the fuel cell as a temporary energy storage element to support startup or sudden load changes because the fuel cells can not immediately respond to such abrupt load changes.

However, feeder loading varies from time to time, which will make it very difficult to obtain the desired load balance with the network configuration in the system planning stage. Further, with more and more renewable distributed generation such as wind power and fuel cell power being installed in distribution feeders, loading balance of distribution systems becomes more of a challenge due to the injection of intermittent power generation. Applying power electronics based flexible AC transmission system (FACTS) has been proven highly effective for controlling the load transfer between feeders to achieve loading balance [5].

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-Netalgorithm 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 fuel cell installation, the feeder loading will be varied dramatically. The load transfer between feeders with an open-tie switch must be adaptively adjusted according to fuel cell power generation. Due to the intermittent power generation by fuel cell 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 proposes 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 can reduce 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 fuel cell 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 fuel cell system on feeder loading balance and loss reduction of the distribution system is investigated. Finally, Section V gives conclusions.

II. DISTRIBUTION AUTOMATION SYSTEM WITH LOOP POWER CONTROLLER

To enhance reliability and operation efficiency of distribution systems, the fully integrated distribution automation system (DAS) in Fig. 1 has been implemented by Taiwan Power Company (Taipower). The DAS consists of a master station (MS) with application software, remote terminal units (RTUs) in the substations, feeder terminal units (FTUs), and automatic line switches along the primary feeders [15]. The distribution feeders from substations are connected as the open loop configuration with one of the automatic line switches being selected as the open-tie switch. To achieve loading balance of distribution feeders for normal operation with variation of feeder loading, the non-interruptible load transfer is executed.

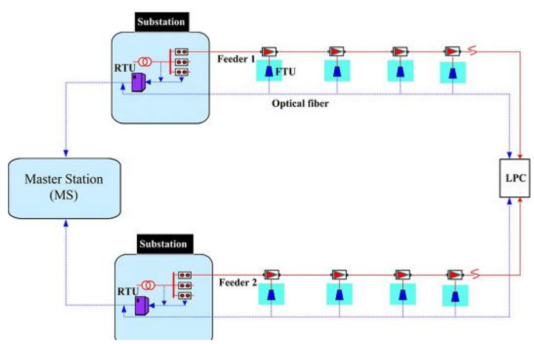

Fig.1. Distribution automation system with a loop power controller.

By closing the open-tie switch and opening one of the normal close switches. When a fault contingency occurs, the feeder circuit breaker trips, and the over-current fault flags of all upstream FTUs are set due to the large fault current flows. After the MS retrieves all fault flags, the fault location can therefore be determined according to the combination of fault flags and the network topology. The MS then sends the command to open all line switches around the faulted section to complete the fault isolation and followed by reclosing the feeder circuit breaker to

INTERNATIONAL JOURNAL OF RESEARCH
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Volume 5, Issue 1 SEP 2015

restore power service to upstream customers. After verifying the reserve capacity of the supporting feeder, the open-tie switch is closed to fulfill the service restoration of downstream customers [16]. Although the DAS has been applied for fault restoration effectively in Taipower, the loading balance is difficult to be performed for distribution system with large DG facility because too frequently the switching operation is required to accommodate the dramatic fluctuation of DG generation. To solve the problem, Fig. 1 shows how the proposed LPC is applied to replace the open-tie switch by achieving adaptive power flow control for load transfer. The distribution feeder-pair with LPC provides the following advantages: 1) improved controllability and operational flexibility of the distribution system; 2) mitigation of voltage fluctuation with fast reactive power compensation; 3) control of the real and reactive power flow; 4) reduced power system loss with improved loading balance of the distribution system; and 5) enhanced system robustness for integration with more renewable energy [11].

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.

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

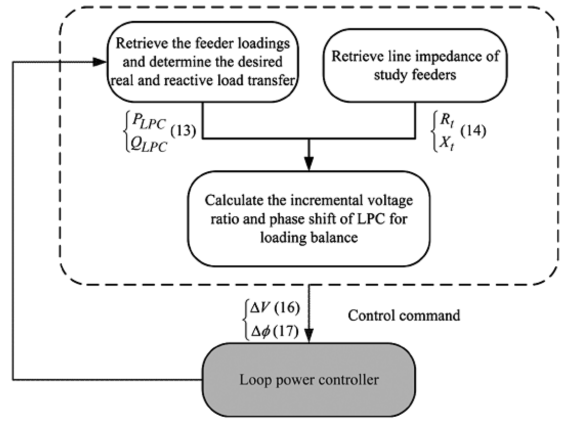

Fig.2. Flowchart of LPC control algorithm.

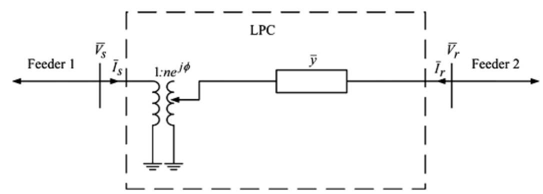

Fig.3.Circuit model of loop power controller.

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: and a series admittance y. 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 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 shift as follows:

$$I_s=n^2\bar{y}\bar{V}_s-n\bar{y}\bar{V}_r$$

$=(n^2-1)\bar{y}\bar{V}_s + (1-n)\,\bar{y}\bar{V}_r + \bar{y}(\bar{V}_s - \bar{V}_r)$ (2)

$I_r = -n^2\bar{y}\bar{V}_s - n\bar{y}\bar{V}_r$

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

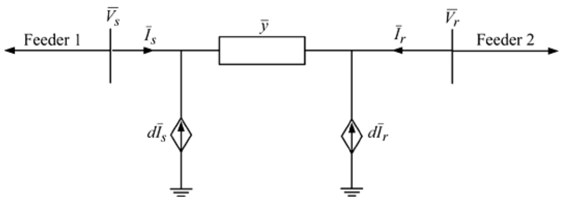

Fig.4. Modified equivalent circuit model of LPC.

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:

$I_S = \bar{y}\bar{V}_s - \bar{y}e^{-j\emptyset}\bar{V}_r$

$= (1-e^{-j\emptyset})\,\bar{y}\bar{V}_r + \bar{y}(\bar{V}_s - \bar{V}_r)$ (6)

$= (1-e^{-j\emptyset})\,\bar{y}\bar{V}_s + \bar{y}(\bar{V}_r - \bar{V}_s)$ (7)

The equivalent injection currents are solved as

$dI''_S = -(1-e^{-j\emptyset})\,\bar{y}\bar{V}_r$ (8)

$dI''_r = -(1-e^{-j\emptyset})\,\bar{y}\bar{V}_{s^*}$ (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)

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

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

B. LPC 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

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

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

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

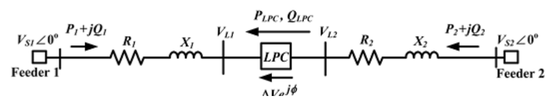

Fig.5. Incremental circuit model of distribution feeders with LPC.

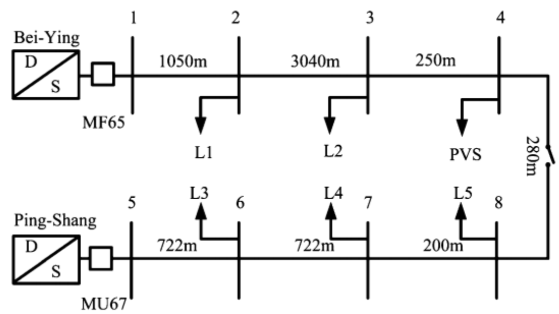

Fig.6. Taipower distribution feeders for computer simulation.

In order to perform the LPC control strategy to have the proper load transfer between both feeders for loading balance, the terminal voltage at the primary side of LPC is assumed to have a fixed value of. The terminal voltage at the secondary side of LPC is derived in (15):

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

The incremental terminal voltage and phase shift are therefore calculated as follows:

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

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

FUEL CELL

A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained. Fuel cells are different from conventional electrochemical cell batteries in that they consume reactant from an external source, which must be replenished[1] – a thermodynamically open system. By contrast, batteries store electrical energy chemically and hence represent a thermodynamically closed system.

Many combinations of fuels and oxidants are possible. A hydrogen fuel cell uses hydrogen as its fuel and oxygen (usually from air) as its oxidant. Other fuels include hydrocarbons and alcohols. Other oxidants include chlorine and chlorine dioxide Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three segments which are sandwiched together: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electrical current is created, which can be used to power electrical devices, normally referred to as the load.

At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electrical current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.

FUEL CELL APPLICATIONS:

POWER:

Fuel cells are very useful as power sources in remote locations, such as spacecraft, remote weather stations, large parks, rural locations, and in certain military applications. A fuel cell system running on hydrogen can be compact and lightweight, and have no major moving parts. Because fuel cells have no moving parts and do not involve combustion, in ideal conditions they can achieve up to 99.9999% reliability. This equates to around one minute of down time in a two year period.Since electrolyses systems do not store fuel in themselves, but rather rely on external storage units, they can be successfully applied in large-scale energy storage, rural areas being one example. In this application, batteries would have to be largely oversized to meet the storage demand, but fuel cells only need a larger storage unit (typically cheaper than an electrochemical device).

Cogeneration:

Micro combined heat and power (MicroCHP) systems such as home fuel cells and cogeneration for office buildings and factories are in the mass production phase. The system generates constant electric power (selling excess power back to the grid when it is not consumed), and at the same time produces hot air and water from the waste heat. MicroCHP is usually less than 5 kW for a home fuel cell or small business. A lower fuel-to-electricity conversion efficiency is tolerated (typically 15-20%), because most of the energy not converted into electricity is utilized as heat. Some heat is lost with the exhaust gas just as in a normal furnace, so the combined heat and power efficiency is still lower than 100%, typically around 80%. In terms of energy however, the process is inefficient, and one could do better by maximizing the electricity generated and then using the electricity to drive a heat pump. Phosphoric-acid fuel cells (PAFC) comprise the largest segment of existing CHP products worldwide and can provide combined efficiencies close to 90% (35-50% electric + remainder as thermal) Molten-carbonate fuel cells have also been installed in these applications, and solid-oxide fuel cell prototypes exist.

Other applications:

- Providing power for base stations or cell sites
- Off-grid power supply

- Distributed generation
- Fork Lifts
- Emergency power systems are a type of fuel cell system, which may include lighting, generators and other apparatus, to provide backup resources in a crisis or when regular systems fail. They find uses in a wide variety of settings from residential homes to hospitals, scientific laboratories, data centers, telecommunication equipment and modern naval ships.
- An uninterrupted power supply (UPS) provides emergency power and, depending on the topology, provide line regulation as well to connected equipment by supplying power from a separate source when utility power is not available. Unlike a standby generator, it can provide instant protection from a momentary power interruption.
- Base load power plants
- Electric and hybrid vehicles.
- Notebook computers for applications where AC charging may not be available for weeks at a time.
- Smartphone with high power consumption due to large displays and additional features like GPS might be equipped with micro fuel cells.
- Small heating appliances.

Fuel cells are a technology that both the public and private sectors are increasingly turning to for both primary and back-up power needs. Although the understanding of the chemistry of fuel cells goes back more than a century, they are very much a 21st century technology. The basic design and electrochemical principle behind fuel cells is straightforward. A fuel cell stack requires only hydrogen (or a similar energy carrier), oxygen, and an electrolytic solution.

Hydrogen and ambient air flow into the fuel cell, which contains an anode and a cathode. At the anode, the hydrogen separates into a proton and an electron. The proton migrates to the cathode, where it reacts with the oxygen to form water. The electrons, which cannot pass through the membrane, flow from the cell to provide useful electrical power. Fuel cells are quiet, have no moving parts, and produce no particulate emissions. They are virtually maintenance free and can be both tested and operated remotely. Because they are modular, they can be configured for any size power needs, from a few kilowatts for a remote telecommunications tower to megawatt-scale for hospitals and airports. Hydrogen is safely stored on-site or produced within the fuel cell itself.

IV. CASE STUDY OF TAIPOWER DISTRIBUTION SYSTEM

To demonstrate the effectiveness of the proposed LPC for loading balance of distribution feeders with fuel cell facility, a Taipower distribution system serving Kaohsiung Stadium for 2009 World Games in Taiwan has been selected for computer simulation as shown in Fig. 6. A large fuel cell system with 8844 pieces has been installed with total capacity of 1027 kWP. Feeder MF65 is supplied by Bei-Ying substation to serve Kaohsiung Stadium and other low-voltage customers. The feeder is connected to Feeder MU67 with an open line switch so that the load transfer can be executed for service restoration during fault emergency. With such a fuel cell system being installed, it is expected that total annual fuel cell electricity energy of 1.37 GWH can be generated [17]. Fig. 7 shows the one-line diagram of the power system in the stadium. There are 179 units of DC/AC inverters which are used to convert the fuel cell generation to 380 Vac. Besides serving the local loads in the stadium, the surplus power generated by the fuel cell system is also sold to Taipower system.

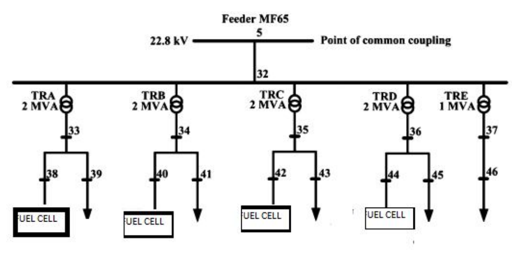

Fig. 7. One-line diagram of Kaohsiung Main Stadium.

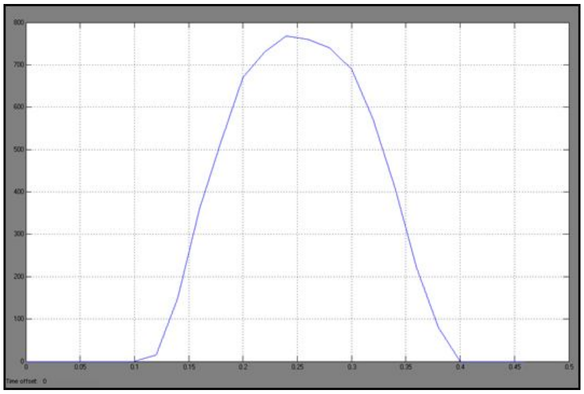

Fig.8. Actual fuel cell power generation of Kaohsiung Stadium (June 30, 2009).

The daily power generation of the study fuel cell system has been recorded by the SCADA system as shown in Fig. 8. It is found that the fuel cell power generation is increased with solar irradiation. The maximum power generation was 768 kWh at 12 PM, and the total harvesting energy of 6702 kWh has been obtained for June 30, 2009.

Fig. 9 shows the reduction of real power loading of Feeder MF65 during daytime period after integrating fuel cell power generation in the distribution system.

A. Loading Balance of Distribution Feeder by a Loop Power Controller

With the variation of customer loading profiles and the intermittent generation of fuel cell 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 fuel cell 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 MF65 and MU67.

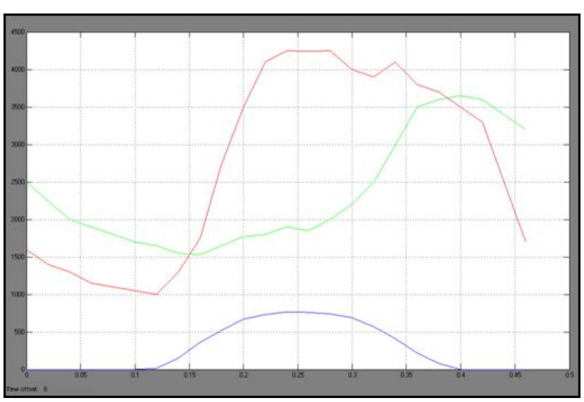

Fig. 9. Power profiles of Feeder MF65 and MU67 (with fuel cell system)

To achieve the loading balance, the voltage ratio and phase shift by LPC have to be revised as shown in Fig.10 according to the variation of PV power generation.

The fuel cell system does not generate reactive power. However, the phase shift of LPC required for real power balancing is increased during the daytime period when the real power generated by the fuel cell system is injected. For instance, a larger phase shift of is applied for real power transfer of 897 kW from MU67 to MF65 at 3 PM. With the control of LPC, the loading balance of test feeders by including the fuel cell power generation has been obtained as shown in Fig. 11. By comparing to Fig. 9, the mismatches of real power and reactive power loadings between Feeder MF 65 and Feeder MU 67 at 3 PM are reduced from 2574kW/1727 kVAR to 191kW/79 kVAR after loading balance.

B. 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 fuel cell system, Fig. 12 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

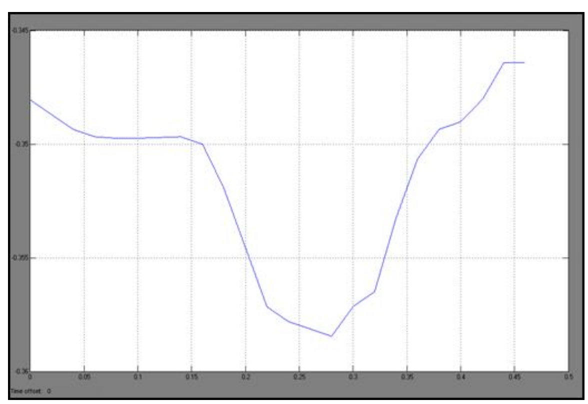

Fig. 10(a). Voltage ratio with the control of LPC (with fuel cell system).

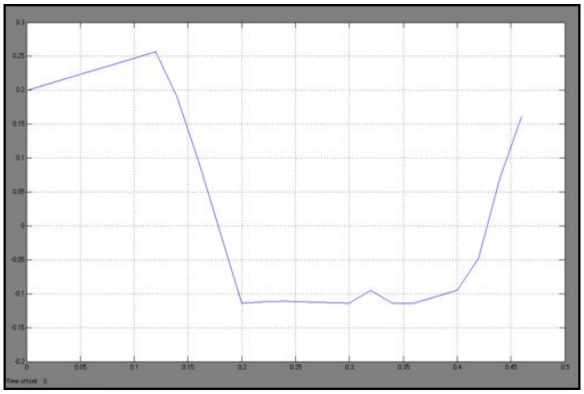

Fig. 10(b). Phase shift with the control of LPC (with fuel cell system).

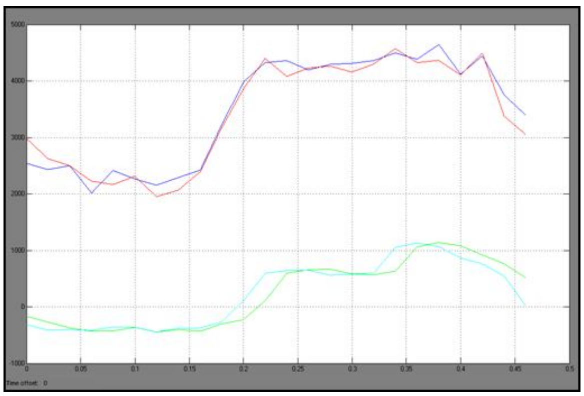

Fig. 11. Loading balance of both feeders with the control of LPC (with fuel cell system).

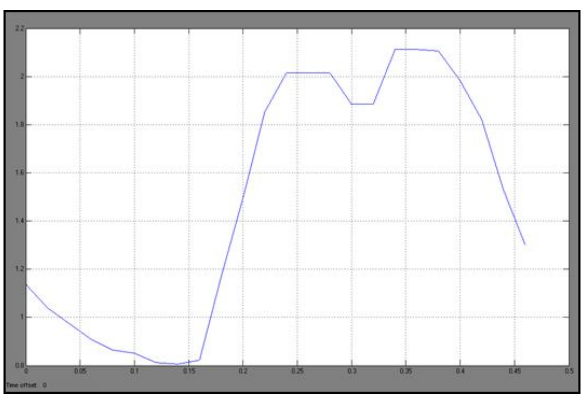

Fig. 12(a). Percentage of system power loss before applying LPC for loading balance (with fuel cell system).

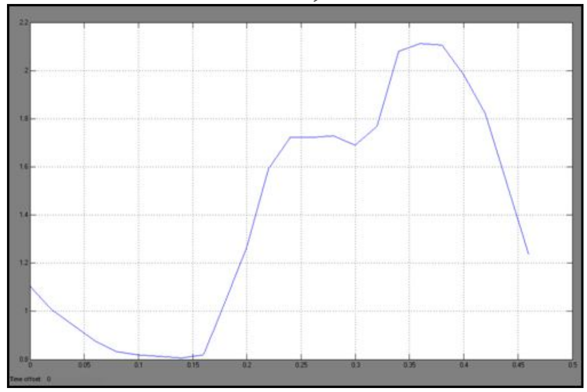

Fig. 12(b). Percentage of system power loss after applying LPC for loading balance (with fuel cell system).

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.

V. 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 fuel cell system has been selected for computer simulation. The power loadings of the study feeders and the fuel cell 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 fuel cell 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] M. N. Marwali and A. Keyhani, "Control of Distributed Generation Systems, Part I: Voltages and Currents Control," IEEE Transaction on Power Electronics, vol. 19, pp. 1541-1550, Nov. 2004.
[2] M. N. Marwali, J. W. Jung, and A. Keyhani, "Control of Distributed Generation Systems, Part II: Load Sharing Control," IEEE Trans. on Power Electronics, vol. 19, pp. 1551-1561, Nov. 2004.
[3] A. A. Chowdhury, S. K. Agarwal, D. O. Koval, "Reliability modeling of distributed generation in conventional distribution systems planning and analysis," IEEE Transactions on Industry Applications, vol. 39, pp. 1493-1498, Sept.-Oct. 2003.
[4] T. Monai, I. Takano, H. Nishikawa, and Y. Sawada,"Response characteristics and operating methods of new type dispersed power supply system using photovoltaic fuel cell and SMES," IEEE Power Engineering Society Summer Meeting, vol. 2, pp. 874-879, July 2002.
[5] J. L. Del Monaco, "The Role of Distributed Generation in the Critical Electric Power Infrastructure," IEEE-Power Engineering Society Winter Meeting, vol. 1, pp. 144 -145, 2001.
[6] L. Philipson, "Distributed and Dispersed Generation: Addressing the Spectrum of Consumer Needs," IEEE-Power Engineering Society Summer Meeting, vol. 3, pp. 1663 -1665, 2000.
[7] K. Sedghisigarchi and A. Feliachi, "Dynamic and Transient Analysis of Power Distribution Systems With Fuel Cells-Part I: Fuel-Cell Dynamic Model," IEEE Transactions on Energy Conversion, vol. 19, pp. 423- 428, June 2004.
[8] K. Sedghisigarchi and A. Feliachi, "Dynamic and Transient Analysis of Power Distribution Systems With Fuel Cells-Part II: Control and Stability Enhancement," IEEE Transactions on Energy Conversion, vol. 19, pp. 429-434, June 2004.
[9] L.Y. Chiu and B. M. Diong, "An improved smallsignal model of the dynamic behavior of PEM fuel cells," IEEE 38th IAS Annual Meeting, vol. 2, pp. 709-715, Oct. 2003.
[10] J. T. Pukrushpan, H. Peng, and A. G. Stefanopoulou, "Simulation and analysis of transient fuel cell system performance based on a dynamic reactant flow model," Proc. of ASME IMECE'02, 2002.
[11] S. Yerramalla, A. Davari, A. Feliachi, "Dynamic modeling and analysis of polymer electrolyte fuel cell,"IEEE Power Engineering Society Summer Meeting,vol. 1, pp. 82-86, July 2002.
[12] J. T. Pukrushpan, A. G. Stefanopoulou, and H. Peng, "Modeling and control for PEM fuel cell stack system," American Control Conference, vol. 4, pp. 3117-3122, May 2002.
[13] K. H. Hauer, "Dynamic interaction between the electric drive train and fuel cell system for the case of an indirect methanol fuel cell vehicle,"35th IECEC Meeting, vol. 2 , pp. 1317-1325, July 2000.
[14] Yoon-Ho Kim and Sang-Sun Kim, "An electrical modeling and fuzzy logic control of a fuel cell generation system," IEEE Transactions on Energy Conversion, vol. 14, no. 2, pp. 239-244, June 1999.
[15] G. K. Andersen, C. Klumpner, S. B. Kjaer, and F.Blaabjerg, "A new green power inverter for fuel cells,"IEEE PESC'02, vol. 2, pp. 727-733, June 2002.
[16] R. Gopinath, Sangsun Kim, Jae-Hong Hahn, M. Webster, J. Burghardt, S. Campbell, D. Becker, P. Enjeti, M. Yeary, and J. Howze, "Development of a low cost fuel cell inverter system with DSP control," IEEE PESC'02, vol. 1, pp. 309-314, June 2002.
[17] A. M. Tuckey and J. N. Krase, "A low-cost inverter for domestic fuel cell applications,"IEEE PESC'02,vol. 1, pp. 339-346, June 2002.
[18] E. Santi, D. Franzoni, A. Monti, D. Patterson, F. Ponci, and N. Barry, "A fuel cell based domestic uninterruptible power supply," IEEE APEC'02, vol.1, pp.605-613, March 2002.
[19] A. Bendre, G. Venkataramanan, and D. Divan, "Dynamic analysis of loss-limited switching full-bridgeDC-DC converter with multimodal control," IEEE Transactions on Industry Applications, vol. 39, pp. 854-863, 2003.
[20] M. T. Aydemir, A. Bendre, and G. Venkataramanan,"A critical evaluation of high power hard and soft switched isolated DC-DC converters," IEEE IAS'02,vol. 2, pp. 1338-1345, Oct. 2002.
[21] Eun-Soo Kim, Kee-Yeon Joe, Moon-Ho Kye, Yoon-Ho Kim, and Byung-Do Yoon, "An improved ZVZCS PWM FB DC/DC converter using energy recovery snubber," IEEE APEC'97, vol. 2, pp. 1014-1019, Feb. 1997.
[22] P. K. Jain, Wen Kang, H. Soin, and Youhao Xi, "Analysis and design considerations of a load and line independent zero voltage switching full bridge DC/DC converter topology," IEEE Transactions on Power Electronics, vol. 17, pp. 649-657, Sept. 2002.
[23] M. Brunoro and J. L. F. Vieira, "A high-performance ZVS full-bridge DC-DC 0-50-V/0-10-A power supply with phase-shift control," IEEE Transactions on Power Electronics, vol. 14, pp. 495-505, May 1999.
[24] Seong-Jeub Jeon and Gyu-Hyeong Cho, "A zerovoltage and zero-current switching full bridge DC-DC converter with transformer isolation," IEEE Transactions on Power Electronics, vol. 16, pp. 573-580, Sept. 2001.

[25] F. Z. Peng, Hui Li, Gui-Jia Su, and J. S. Lawler, "A new ZVS bidirectional DC-DC converter for fuel cell and battery application," IEEE Trans. on Power Electronics, vol. 19, pp. 54-65, Jan. 2004.
[26] Z. Jiang and R. A. Dougal, "Control design and testing of a novel fuel-cell-powered battery-charging," IEEE APEC'03, vol. 2, pp. 1127-1133, Feb. 2003.

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