View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Elsevier - Publisher Connector

Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 86 (2016) 124 – 127

Procedia Computer Science

2016 International Electrical Engineering Congress, iEECON2016, 2-4 March 2016, Chiang Mai, Thailand

TS-Fuzzy based Adaptive PEVs Charging Control for Smart Grid Frequency Stabilization under Islanding Condition

Chaowanan Jamroen, Pipatpan Namproom, Sanchai Dechanupaprittha*

Department of Electrical Engineering, Faculty of Engineering, Kasetsart University, Bangkok, 10900, Thailand

Abstract

This paper presents Takagi-Sugeno (TS) fuzzy based adaptive charging power control of plug-in electric vehicles (PEVs) connected to smart grid, intended to improve the performance of frequency stabilization for smart grid and to reduce the impact on consumers from traditional stability solution, i.e. load shedding, especially when unintentional islanding of the system occurs. Simulation results using DIgSILENT reveal the performance and effectiveness of the proposed approach.

© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the Organizing Committee of iEECON2016

Keywords: : PEVs Charging Control; Frequency Stabilization; Fuzzy based Adaptive; Smart grid

1. Introduction

The energy efficiency and environmental issues receive more attention nowadays. Both concerns yield all over the world towards reducing energy consumptions from non-renewable energy sources and increasing use of alternative energy generated from renewable energy source (RES), which is more sustainable. RES is environmentally friendly and has been promoted for a smart grid, which is expected to have advanced communication and controllability. With proper control scheme, a smart grid can help authority to manage use of energy more effectively [1]. Moreover, with ability to control load, power system stability problems can be mitigated, while reducing impact on consumers and increasing security of a power system [2].

*Corresponding author. Tel.: +662-797-0999 ext.1575; fax: +662-797-0999 ext.1550.
E-mail address: chaowanan.j@ku.th (C. Jamroen), pipatpan_n@hotmail.com (P. Namproom), sanchai.d@ku.ac.th (S. Dechanupaprittha).

1877-0509 © 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the Organizing Committee of iEECON2016
doi:10.1016/j.procs.2016.05.031

Unintentional Islanding is often caused by a short circuit or malfunction of protection. This event affects various aspects on smart grid; for example, operating frequency of a system embedded with distributed generation (DG) changes abruptly without proper control measure. It can cause power outage or blackout, however, depending on severity of the situation and also a prepared countermeasure [3].

The islanding problem has been studied, and some solutions have been revealed, for example, load shedding scheme. Moreover, another interesting approach such as load controlling has been developed by integrating controller within a load itself to receive power control signal [4]. The load control method might create inconvenience to consumers; nevertheless with proper scheme it could be hardly noticeable. This paper presents Takagi-Sugeno (TS) fuzzy based adaptive charging power control of plug-in electric vehicles (PEVs) to enhance the resilience and performance of modern power system. A frequency deviation criterion is determined for charging power control of PEVs to improve frequency stabilization of a power system.

2. Takagi-Sugeno (TS) Fuzzy

TS fuzzy is based on modified Mamdani fuzzy inference system. Fuzzification of the inputs and the fuzzy operator are exactly the same. The main difference between Mamdani and TS is the output membership functions [5]. The output of TS is either linear or constant value. Therefore, it is suitable for many applications. Rules of the TS form can be explained by Eq. 1.

$$R_i \ : \ IF \ x_1 = P_1^K \ and \ x_2 = P_2^L \ and \cdots \ x_n = P_n^M \ , \ then \ q^i \ = \ f_i \tag{1}$$

where R_i is the rule of the form, $x_{1,2,n}$ are the input of fuzzy, $P_{1,2,n}^{K,L,M}$ is fuzzy set, q^i is the output of rule i, f_i is memoryless function. The defuzzification process uses a weighted average method to find final output of TS fuzzy.

3. Fuzzy Controller Design

Membership functions are designed for two inputs, ΔP_{GS} and Δf , as shown in Fig. 1 (a) and (b). The rules of the controller are listed in Table 1. Each membership function is designed by changing its possible range. The consideration of parameter adjustment can be divided into 3 designated ranges, i.e. Normal, Off-normal and Emergency. Each range will be adjusted based on its importance; operating frequency range and available energy source in the area.

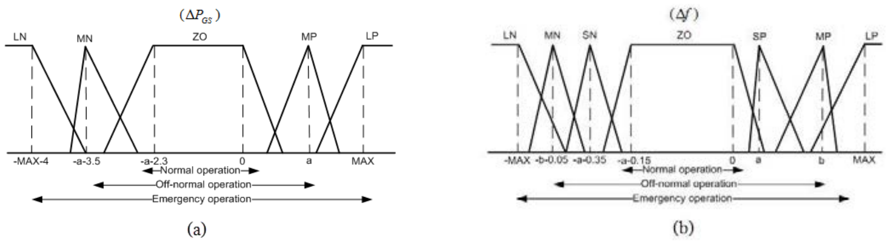


Fig. 1. (a) Membership function of ΔP_{GS} input; (b) Membership function of Δf input

Table 1. TS-Fuzzy rules of the controller

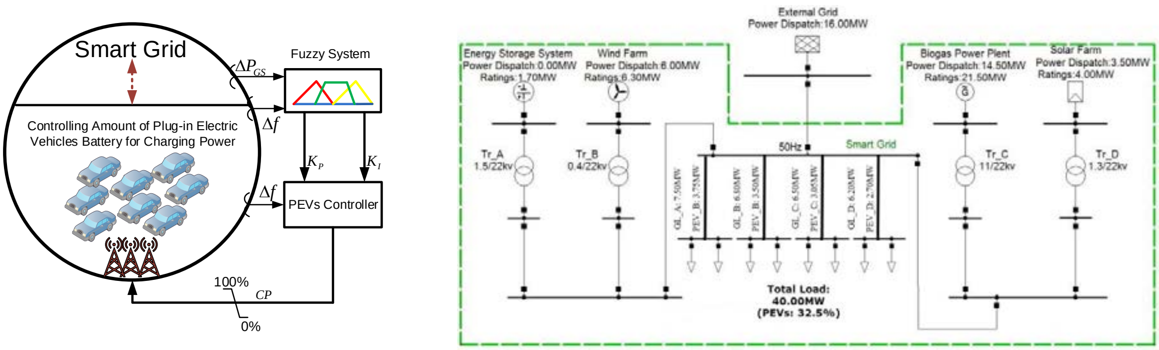
Rule	LN	MN	SN	ZO	SP	MP	LP
ΔP_{GS}	KI_{LN}	KI_{MN}	-	KI_{ZO}	-	KI_{MP}	KI_{LP}
Δf	KP_{LN}	KP_{MN}	KP_{SN}	KP_{ZO}	KP_{SP}	KP_{MP}	KP_{LP}

4. Charging Power Control of PEVs

Charging power control of PEVs in the area by using PI (Proportional-Integral) structure with fuzzy based adaptive scheme can be presented in Fig. 2 (a). *CP* is the percentage of charging power of PEVs in the area. The value ranges between 0 to 100 %. In a normal situation, the value of *CP* is equal to 100% that means electric vehicles in the area are charged with maximum charging power. In case problem of instability, *CP* will be adjusted according to frequency deviation (Δf). The decision of fuzzy system will control value of K_P and K_I to adjust suitable *CP* signal with the incident. *CP* can be determined by Eq.2 and $P_C = P_{PEV} \times CP$.

$$CP = K_P \Delta f + K_I \int \Delta f \; dt \tag{2}$$

P_{PEV} is a charging capacity of each PEV. The fuzzy inputs to adjust the values of K_P and K_I are Δf and power deviation of the source for secondary frequency control (ΔP_{GS}). The relationship of fuzzy decision to adjust K_P depends on the value of Δf, means in case of frequency deviation occurs K_P will affect the first peak value of system frequency. Appropriate adjustment of K_P is like being adjustment of charging status, which will maintain frequency to avoid reaching activation point of Automatic Under Frequency Load Shedding (AUFLS). This reduces the chance of wide-area outage and also significantly increases performance of energy management. K_I depends on value of ΔP_{GS} , which means that in case of increase in ΔP_{GS} will result in Area Spinning Reserve's decrease. It is a sign of stability issues that may occur in the area. Appropriate adjustment of K_I is like being charging power adjustment to help reducing system swing and maintaining frequency.



(a) (b)

Fig. 2. (a) The control scheme of PEVs charging; (b) Smart grid study system

5. Simulation Study

Fig. 2 (b) shows a model using DIgSILENT PowerFactory for the smart grid study system, 24 kV, 50 Hz connected to an external grid. The simulation scenario starts with the system facing unintentional islanding situation and yields the changes of frequency when only local generation supplies power in the area. As a result, the occurrence of the islanding incident rapidly decreases frequency of smart grid embedded with DG as shown by dotted line in Fig. 3 (a) due to active power generation is not sufficient, which results as frequency drop to the activation point of AUFLS. For charging power control of PEVs, Fuzzy-PI controller adjusts *CP* signal equal to 23.3% as shown by solid line in Fig. 3 (b) and has been able to maintain frequency at 49.214 Hz as shown by solid line in Fig. 3 (a). This point is above the activation point of AUFLS, different from the PI control as shown by dashed line in Fig. 3 (a), *CP* signal falls to 49.91% while frequency drops to 48.861 Hz as shown by dashed line in Fig. 3 (b), which activates operation of AUFLS. The study also focuses on the performance of charging power control of PEVs when load and solar energy fluctuations occurred during islanding operation as shown in Fig. 4 (a). During islanding mode, Fuzzy-PI shows better performance as system frequency deviation remains within 0.414 Hz (max to min); in comparison PI yields a system frequency deviation below 0.814 Hz, as shown in Fig. 4 (b). More specifically, Fuzzy-PI yields better frequency stabilization compared with PI.

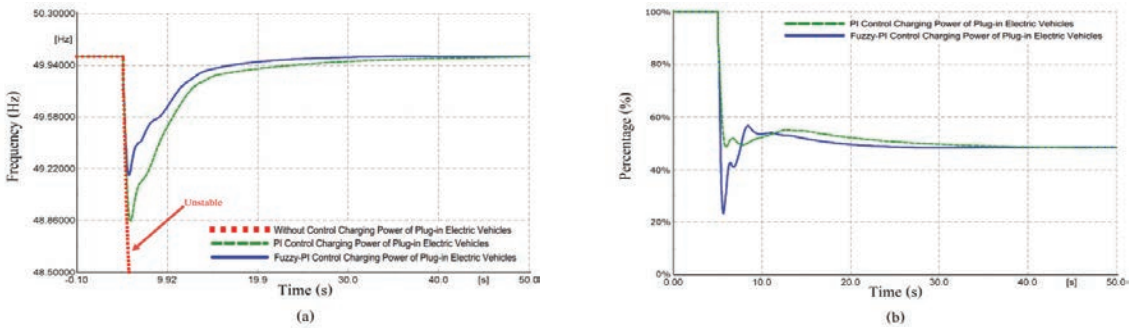


Fig. 3. (a) System frequency while islanding occurred; (b) CP signal while islanding occurred

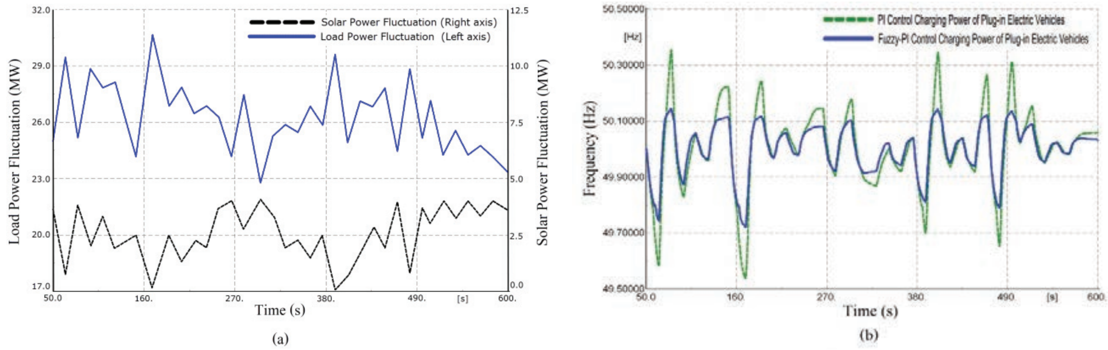


Fig. 4. (a) Load and Solar power fluctuations while islanding mode; (b) System frequency while islanding mode

Conclusion

TS fuzzy based adaptive charging power control of PEVs has shown interesting and promising results. It can be adjusted for more efficient than conventional PI. The simulation results show that when the system was disturbed, system frequency deviation was suppressed, reducing the chance of power outages as well. The proposed method is able to enhance the resilience of smart grid and security of smart grid operation; meanwhile reduce adverse impact on consumers from traditional stability solution, i.e. load shedding.

Acknowledgements

Authors would like to thank the Thailand Research Fund grant no. TRG5780271 and Kasetsart University Research and Development Institute for financial research supports.

References

[1] I. Ngamroo, Power System Dynamics and Stability. King Mongkut's Institute of Technology Ladkrabang, 2011.

[2] M. Sengnongban, S. Dechanupaprittha, Control Strategy of PEVs Charging for Reducing the Impact of Power Fluctuations in Micro Grid, IEECON 2014, pp. 1-4, March2014.

[3] P. Kundur, Power System Stability and Control, McGraw-Hill, Inc., 1994.

[4] D. Trudnowski, R. Munson, D. Harvey, M. Donnelly, Frequency and Stability Control using Decentralized Interlligent Loads, IEEE PES GM 2010, pp. 1-6, Jul 2010.

[5] H. Lilly, Fuzzy Control and Identification, John Wiley & Sons, Inc., 2010.