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International Journal for Modern Trends in Science and Technology, 8(01): 38-42, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0801007
Available online at: http://www.ijmtst.com/vol8issue01.html

Various Control Modes of HPFC Under Normal and Fault Conditions

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To Cite this Article
Rashmi M C and Veena H S. Various Control Modes of HPFC Under Normal and Fault Conditions. *International Journal for Modern Trends in Science and Technology* 2022, *8* pp. 38-42. https://doi.org/10.46501/IJMTST0801007

Article Info
Received: 24 November 2021; Accepted: 31 December 2021; Published: 03 January 2022

ABSTRACT

**Flexible Alternating Current Transmission System (*FACTS) provide better prospects to control the power systems effectively, as well as they improve power transfer capabilities. These devices also address few of the challenges, which are faced by the grid. Furthermore, with the advancements of distribution systems along with the distribution generation, storing devices and rising electrical loads add to the difficulties. This is effectively addressed by FACTS controllers, which are based on power electronic components. The high capital investment of the controllers is the major drawback for using these controllers in power system. Therefore, new FACTS controller is introduced which is cost effective and provides similar characteristics to that of the Unified*Power Flow Controller (UPFC). This newly introduced device comprises of converters along with passive components and is called Hybrid Power Flow Controller (HPFC). In this paper, the performance of HPFC under normal and fault conditions is presented. In the MATLAB environment, the simulation results are generated.*

KEYWORDS: Flexible Alternating Current Transmission System (*FACTS), Unified Power Flow Controller (UPFC), Hybrid Power Flow Controller (HPFC).*

1.INTRODUCTION

Flexible Alternating Current Transmission System (FACTS) provide better prospects to control the power systems effectively, as well as they enrich power transfer capabilities [1]. The electric power is conveyed to its customers by high voltage transmission lines and medium or low voltage distribution networks, all of which are subjected to various challenges. With the growing usage of renewable energy sources and increased demand patterns with the population, it is difficult to predict the power flow patterns. Another important aspect to be considered is the old transmission networks which are not designed to accommodate theses kind of power flows and hence this will push the grid to the capability limits.

Thus, power electronics-based components, known as Flexible Alternating Current Transmission System (FACTS) are proposed to address this. Various FACTS controllers namely static*VAR compensator (SVC), thyristor-controlled*series capacitor (TCSC), thyristor-controlled*voltage regulator (TCVR), thyristor-controlled phase shifting transformer (TCPST), static synchronous series compensator (SSSC), unified power flow controller (UPFC) and static synchronous compensator (STATCOM) are proposed [2]. Among all these controllers, UPFC controls parameters such as bus voltage magnitudes and transmission line's active and reactive power independently. Thus, it is the most versatile controller [3]. The usage of UPFC to solve congestion has been demonstrated [4]. Even though the FACTS devices have the capability of controlling voltage magnitudes and flows, their initial capital investment becomes major obstacle for their wide use in power systems.

Therefore, new FACTS controller that is cost effective is proposed which provides the characteristics similar to that of UPFC, and is called as Hybrid Power Flow Controller (HPFC) [5]. HPFC comprises of converters and passive components. HPFC uses half the size of converters and passive components to supply the required quantity of reactive power [5]. HPFC increases the maximum load ability and thus the power transfer capacity of the system. HPFC is modelled using an Electromagnetic Transients Program [6]. The performance of HPFC is compared with that of UPFC [7]. In the current paper, various modes of HPFC under normal and fault conditions are studied.

2.Various Control Modes of HPFC

The possible control modes of HPFC are shown in Fig 1, each of which is explained next in detail.

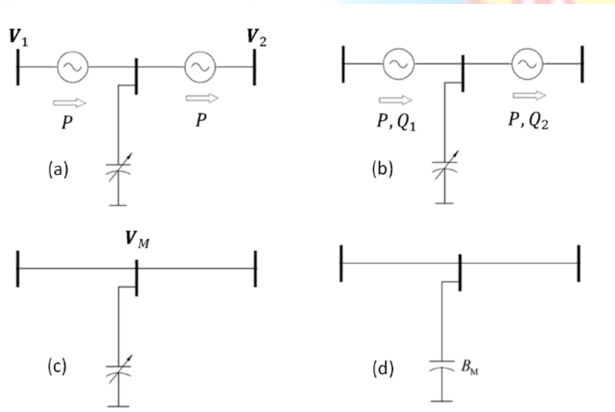

Figure.1. Various Control Modes of HPFC.

(a)PVV Mode (b) PQQ Mode (c) V Mode (d) Z Mode

PVV MODE:

This is the default control mode. In PVV mode, the device will control the active power flow and the terminal voltages at a certain level. This is possible as long as the HPFC stays within the capability limits. If there is any limit violation, which cannot be relieved even after changing B_M, then HPFC switches to PQQ mode. After switching to PQQ mode, limit violations are solved. If there is non-convergent power flow, then the device will switch to V mode.

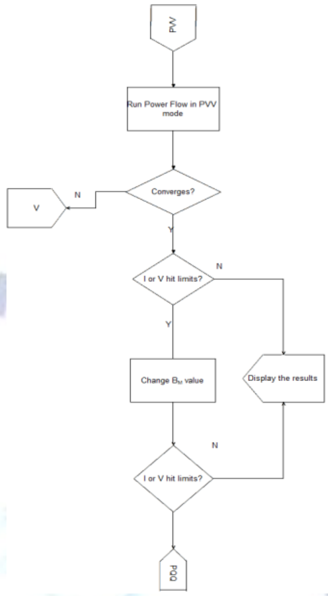

Figure.2. Control Strategy in PVV Mode.

PQQ MODE:

This mode makes an effort to keep the currents and voltages relieved from the limits at the same time. This depends upon the sensitivity of the power injections of the device with reference to the magnitudes of device internal voltage and current. B_M in this mode is a discrete parameter. From the figure, it is seen that in order to bring the device within the capability limits, voltages and currents will be modified, which is done using sensitivity analysis. A proper value of B_M is chosen. The sensitivity matrix G and limit violation magnitude are used to calculate the new values of P, Q_1 and Q_2. Power flow is run using the new values of P, Q_1 and Q_2. If the power flow solution converges then the results are again validated for limit violation. Else, the power flow is repeated by halving the incremental step. This process is repeated several times until the convergence is reached. Similarly, the limit violations are checked for few more iterations. In either of the above, if the maximum number of iterations without resolving the limit violation or without power flow convergence, the device will switch to V mode, where power regulation is relaxed. If not, the final results will be displayed.

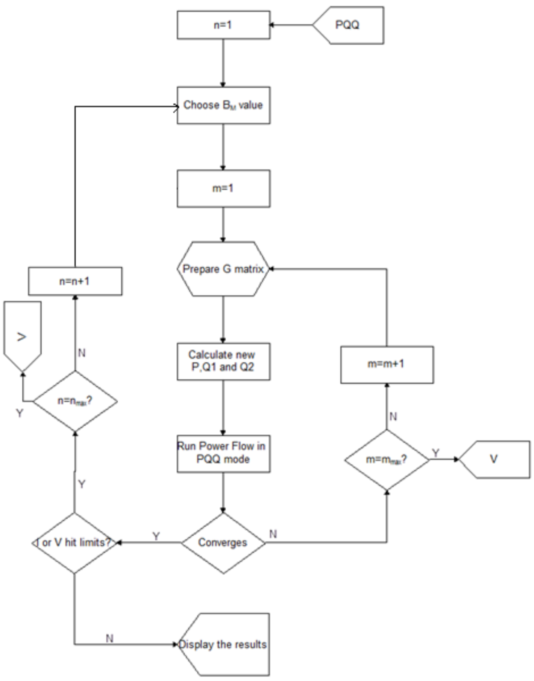

Figure.3. Control Strategy in PQQ Mode.

V MODE:

Here, series voltage sources are bypassed and the terminal voltages are made equal to V_M in this mode. Here B_M is used to regulate the terminal voltage magnitudes. There is no control of active power flow in this mode by the device. It is assumed that the device terminals along with the shunt bus are considered as one bus with the voltage magnitude being regulated. The power flow is run with the above assumption.

In case, the power flow does not converge, the device will switch to Z mode. On the other hand, the highest of input and output currents are compared with the inverter current limits. If they are within the prescribed limits, the device will switch to PQQ mode, or else the required value of B_M is found out depending on the injection of reactive power at shunt bus. If new value of B_M exceeds the maximum limit of the shunt device, B_M is kept constant at B_{Mmax} and the device will switch to Z mode. If not, the device will remain in V mode and the results will be displayed as final. The voltage set point values will vary corresponding to the values of B_M in this mode.

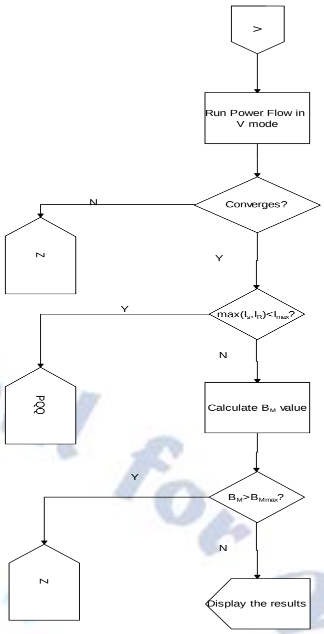

Figure.4. Control Strategy in V Mode.

Z MODE:

Here, HPFC is relieved of maximum constraints and thus the device is in its minimum capability. The maximum value of B_M is considered and V_1=V_2=V_M. Accordingly, in the power flow analysis, the device thus acts as passive fixed shunt susceptance.

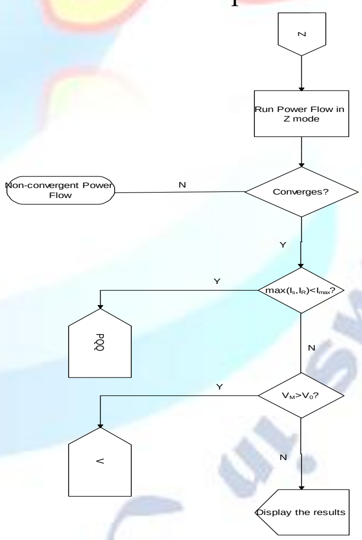

Figure.5. Control Strategy in Z Mode.

3.RESULTS

The modified Kundur’s two-area test system is used for analysis [8]. Here bus 9 is assumed as sink and bus 2 as source respectively and then the loadability studies are performed. The power transfer between the nodes 9 and 2 is increased until the power flow cannot be resolved with the gradual increase of load in steps of 0.1 p.u. the device parameters are:

- $|I_{Smax}| = |I_{R}\,max| = 2$ p.u.
- $|V_{Xmax}| = |V_{Ymax}| = 0.04$ p.u. (9.2 kV)
- B_M can vary between 0 and 0.8 p.u. in equal steps of 0.2 p.u.
- Active power share of lower corridor when compared to the total tie line flow: 25%
- Voltage magnitude at the terminals: 0.9557 p.u.

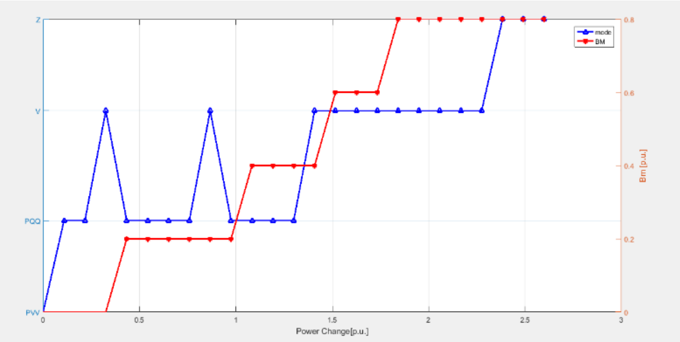

Figure.6. Various Control modes of HPFC and B_M with increase in loading level.

Fig 6 depicts the various control modes of HPFC and B_M with the increase in the load. It is seen that the device will start in the default PVV mode and it jumps to the various modes depending on the requirements of the system with the increase of load. The device finally reaches the Z mode when it has exhausted its capability limits.

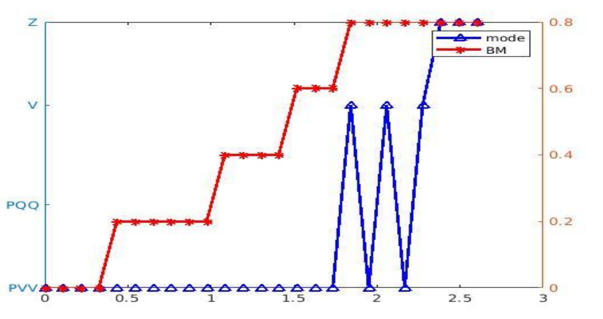

Figure.7. Various Control modes of HPFC during SLG fault at bus 9.

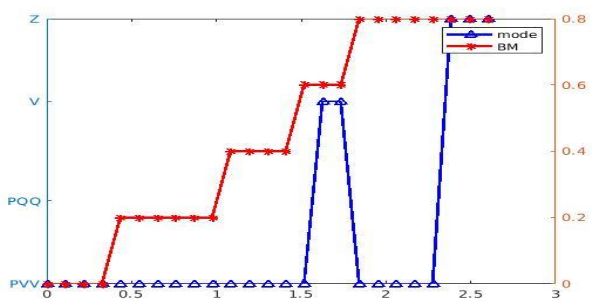

Figure.8. Various Control modes of HPFC during SLG fault at bus 7.

It is seen from the above graphs that the HPFC toggles between different modes according to the requirements of the system. It is also observed that HPFC settles in the Z mode for last incremented values of the load indicating that the HPFC has exhausted its capability completely.

4.Conclusion

To increase the power transfer capacity in the transmission line, the FACTS devices are widely used in power system. In this project, modified Kundur two area test system is used for analysis. This study includes HPFC to get the various possible control modes of HPFC without and with SLG fault conditions.
The simulation study demonstrates:
(i) Various possible control modes of HPFC.
(ii) Various possible control modes of HPFC during SLG fault conditions.

Acknowledgment

I sincerely thank my guide **Mrs. VEENA H S**, Associate Professor, Department of Electrical Engineering, U.V.C.E, Bangalore for her technical guidelines, motivation and suggestions during the course of this work.
I extend my sincere thanks to my parents, family, friends and well-wishers for their moral support during this work.

References

[1] X. P. Zhang, C. Rehtanz, and B. Pal, Flexible ac Transmission Systems, Modelling and Control. Berlin, Germany: Springer 2006.
[2] I. Axente, R. K. Varma and W. H. Litzenberger, "Bibliography of FACTS: 2000 — Part II IEEE working group report," 2011 IEEE Power and Energy Society General Meeting, 2011, pp. 1-6, doi: 10.1109/PES.2011.6039880.
[3] S. Arabi, P. Kundur and R. Adapa, "Innovative techniques in modeling UPFC for power system analysis," in IEEE Transactions on Power Systems, vol. 15, no. 1, pp. 336-341, Feb. 2000, doi: 10.1109/59.852141.
[4] S. Zelingher et al., "Convertible static compensator project-hardware overview," 2000 IEEE Power Engineering Society Winter Meeting. Conference Proceedings (Cat. No.00CH37077), 2000, pp. 2511-2517 vol.4, doi: 10.1109/PESW.2000.847206.
[5] J. Z. Bebic, P. W. Lehn and M. R. Iravani, "The hybrid power flow controller - a new concept for flexible AC transmission," 2006 IEEE Power Engineering Society General Meeting, 2006, pp. 1 pp.-, doi: 10.1109/PES.2006.1708944.

[6] V. K. Sood and S. D. Sivadas, "Simulation of hybrid power flow controller," 2010 Joint International Conference on*Power Electronics, Drives and Energy Systems & 2010 Power India, 2010, pp. 1-5, doi: 10.1109/PEDES.2010.5712553.

[7] N. R. Merritt and D. Chatterjee, "Performance improvement of power systems using Hybrid Power Flow Controller," 2011 International Conference on Power and Energy Systems, 2011, pp. 1-6, doi: 10.1109/ICPES.2011.6156628.

[8] P. Kundur, Power System Stability and Control. New York: McGraw- Hill, 1994.

[9] D. P. Kothari and I. J. Nagrath, "Power System Engineering," 2nd Edition, Tata McGraw Hill, New Delhi, 2007.