179. Under Voltage Load Shedding Scheme to Provide Voltage Stability

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Abstract

Under voltage load shedding (UVLS) plays a vigorous part in power system stability when system is subject to a large disturbance. Load shedding has been employed for long time as the last remedy to protect the power systems from complete Blackouts .This paper proposes an advanced method for under voltage load shedding by incorporating a UVLS Logic relay design in MATLAB Simulink environment. The main enthusiasm for this study is to attain a better performance of UVLS. The proposed methodology is executed on 3-machine 9-bus test system. The voltage is stable if the system can maintain its voltage within acceptable limits when there is a change in load admittance. After the occurrence of 3- phase fault at the terminals of Generator 3 located at Bus 3, simulations results clearly indicates the voltage profile improvement of the week buses if not applied UVLS then power system may proceed towards collapse.

Keywords: Under voltage load shedding; Blackouts; Load shedding; Power system stability.

1. INTRODUCTION

Real and reactive power deficiencies due to generation and overload contingencies in a power system may decline the system frequency and the system voltage. for a stable and reliable electrical power system system frequency and voltage must be maintained within acceptable limits. Both generation and demand depend on these parameters for their own stable and reliable operations. [1]-[2]. Furthermore, Frequency is a system-wide characteristic while voltage is a local feature. Today's electric power systems are often subject to stress due to heavy loading conditions. In addition, the voltage instability is generally created due to component outage or sudden load increments. Now a day's power system has become more complex and heavily loaded due to growth in electricity demand, achieving maximum economic benefits and maximum transmission capacity efficiency. From literature it is observed that major power blackouts that have occurred around the world were caused by voltage instability. Since outage of one or more transmission lines or a sudden tripping of large generating unit may lead the system to collapse. Moreover, due to slow expansion of the transmission system while demands keep increasing, the interconnected power system is pushed closer to operate to its stability limits and it takes times for new corridors of transmission line and added generation so Load shedding must be adopted as last control action in order to avoid system collapse.

Under such conditions, a power system that appears to be functioning adequately could actually be close to instability. The occurrence of a fault or even a slight change in operating conditions can trigger a chain of events leading to a system blackout.

Voltage collapse is an increasing concern for power system operators. The risk of voltage collapse is increasing for several reasons: natural load growth, the changing nature of loads, and dependency on generations located far away from load centres. Power networks are more heavily loaded and are more impacted during disturbances and outages, so the risk of voltage instability increases. An under voltage load shedding (UVLS) can be used to protect the system where the voltage collapse (VC) is expected and can potentially lead to a blackout situation [3]-[4]. The voltage stability phenomenon's are discussed in and is recognized as an important problem for a secure system operation. Hence, UVLS schemes are used to avoid low voltage condition or stop voltage instability. Several papers on UVLS schemes were proposed based upon technical and economical viewpoints. In other words, UVLS is a useful countermeasure in situation where voltage collapse is anticipated. Therefore, UVLS is last resort to protect the system, when other available corrective control actions have been exhausted. Once the voltage magnitude starts to decline, the loads such as motors try to recover the voltage magnitudes by consuming more reactive power. This can exhaust the available reactive power reserve and further cause the voltage magnitudes to drop. The low voltage magnitudes not only affect the local load area, but can also spread throughout adjacent areas of the power system. The proposed UVLS scheme have the capability to handle such situation effetely.

The objective of this paper is to provide an UVLS logic relay design which efficiently deal in the emergency condition without affecting the power system constraints. The next sections outline power system characteristics section II Literature Review section III applications of UVLS schemes section IV Methodology and finally conclusion and results.

2. LITERATURE REVIEW

The UVLS technique is applied by power utilities to prevent voltage instability and restore voltage to its nominal value. The driving force for voltage instability is usually the loads. But still these approached are not effective to control this global problem and minimize the cost of interruption. Voltage instability generally occurs due to either forced outage of the generator or the line, or overloading. To address these issues, in this research study, an under Voltage load shedding scheme is proposed.

2.1 REVIEW OF EXISTING UVLS SCHEME

UVLS is used to avoid a wide area voltage collapse when all other protection mechanisms are exhausted. UVLS operates when there is a system disturbance and the voltage drops below a preselected level for a predetermined time, shedding selected loads [5]-[7]. The intention is that voltage is stabilized or recovered to normal levels when sufficient load is shed. This prevents voltage collapse and restricts a voltage problem within a local area rather than allowing it to spread in geography and magnitude. It is more effective to shed highly reactive loads in the initial stage and then shed the other loads. In many researches the load shedding problem is studied from steady state point of view. In [8] a steady state load shedding scheme based on Genetic Algorithm (GA) method is proposed which considers operational constraints. The developed methodology minimizes the load shedding by considering their importance. Although some event-based schemes have been successfully devised [9], a majority of schemes are of the response-based type [9]- [10] allowing to adjust the corrective action to the disturbance severity and to operate in closed loop for higher robustness.

A few under voltage load shedding schemes have been implemented throughout the world. Several publications on utility implementation of UVLS are available [9]-[11]. The existing schemes are classified as static and dynamic load shedding types. The static scheme sheds a fixed amount of load at each stage, whereas dynamic load shedding sheds a dynamic amount of load based on the magnitude of disturbances and dynamic behaviour of the system at each step. Beside time-domain numerical simulation, methods have been proposed to identify the best location, time and amount of shedding in a given instability scenario.

Some of the developed UVLS schemes consider use of an emergency control loop [12]-[16]. The schemes use control loop load shedding to mitigate the long term voltage instability caused by distributed controllers. An open loop emergency control uses action assessed off-line based on the simulations of postulated scenarios and does not re-adjust its action to follow up the system evolution. On the other hand closed loop assesses the severity through measurements and adjusts its actions correspondingly, and possibly repeating some actions if the previously taken ones are not enough. Several controls are available to correct abnormal voltages: shunt compensation switching, adjustment of generation voltage set points, modifying load tap changers (LTCs) control, and load shedding.

In recent years, some of the optimal load shedding schemes has been used aiming at minimizing the load shedding amount [17]-[23]. The optimization technique has been taken into consideration from various aspects and by means of various techniques such as linear program (LP). Different methods have been studied and evaluated for utilizing its potential in finding the best solution to minimize the amount of loads and maximize the size of voltage improvement. The sensitivities of the load-ability margin and the sensitivities of voltage with respect to the load parameters are often used to determine the optimum load locations.

3. APPLICATION OF UVLS SCHEMES

The Technical Studies Subcommittee of Under-voltage Load shedding Task Force (UVLSTF) of Western Systems Coordinating Council has developed an under voltage load shedding scheme [24]-[25]. They have outlined some points that should be considered when designing a UVLS scheme:

1. Load shedding scheme should be designed in coordination with protective devices and control schemes for momentary voltage dips, sustained faults, low voltages caused by stalled air conditioners, etc.
2. Time delay to initiate load dropping should be in seconds, not in cycles. A typical time delay varies between 3 to 10 seconds.
3. UVLS relays must be on PTs that are connected above the automatic LTCs.

4. Voltage pick-up points for the tripping signals should be set reasonably higher than the “nose point” of the critical P-V or Q-V curve.
5. Voltage pick-up points and the time delays of the local neighbouring systems should be checked and coordinated.
6. Redundancy and enough intelligence should be built into the scheme to ensure reliable operation and to prevent false tripping.
7. Enough loads should be shed to bring voltages to minimum operating voltage levels or higher while Maintaining VAR margins according to WSCC’s Voltage Stability Criteria.

The typical steps selected for a decentralized relay are:

1. 1. Trip 5% of load when monitored bus voltages fall to 90% or lower of normal for minimum of 3.5 seconds.
2. 2. Trip 5% additional load when bus voltages fall to 92% or lower for 5.0 seconds.
3. 3. Trip 5% additional load when bus voltages fall to 92% or lower for 8.0 seconds.

4. MEHODOLOGY

In this research 3 Machine IEEE 9 bus test system is modelled and developed on MATLAB/Simulink platform. It comprise of different generators with different rating, the transmission lines of different lengths are also the part of the system. The variety of loads are connected at different locations. The equipment ratings can be found in the table below.

Table 1. Generator Data [25]

Generator	G1	G2	G3
Rated MVA	247.5	192.0	128.0
kV	16.5	18	13.8
Power factor	1.0	0.85	0.85
Type	hydro	steam	Steam
Speed	180 r/min	3600 r/min	2600 r/min
x_d	0.1460	0.8958	1.3125
x'_d	0.0608	0.1198	0.1813
x_q	0.0969	0.8645	1.2578
x'_q	0.0969	0.1969	0.25
x_l(leakage)	0.0336	0.0521	0.0742
τ'_{d0}	8.96	6.00	5.89
τ'_{q0}	0	0.535	0.6
Stored energy at rated speed	2364 MWs	640 MWs	301 MWs

5. RESULTS AND DISCUSSIONS

For the implementation of the proposed technique of load-shedding, a MATLAB Simulink model results have been developed. In this analysis UVLS schemes are applied to test the system in order to illustrate the behaviour of load shedding schemes, after the 3/phase fault at generator terminals the loss of generator 3.The Power System is interconnected so all the buses get affected after the outage of Generator 3 located at Bus 3.The worst voltages are at buses 1,2,4, 5,6,7 and 8 reaching approximately 0.7 pu (below threshold values) .In figure1 the disturbance shown after the occurrence of fault and in the voltage response of all load buses are shown observation shows that voltages are very low even low then threshold values and need some treatment ,finally figure 1 shown the bus voltage response after the operation of UVLS relay. The relay activated after 3.5 second and curtailed a fixed amount of load (5% of load), the relay activated again after 8.5 seconds because the voltages was still below its threshold value. It is clear from Figure 1 that voltages at all affected buses gets stable approx. 1.pu The Simulation run for 15 seconds and it indicates clearly that voltages attain their thresholds and it regains the stability.

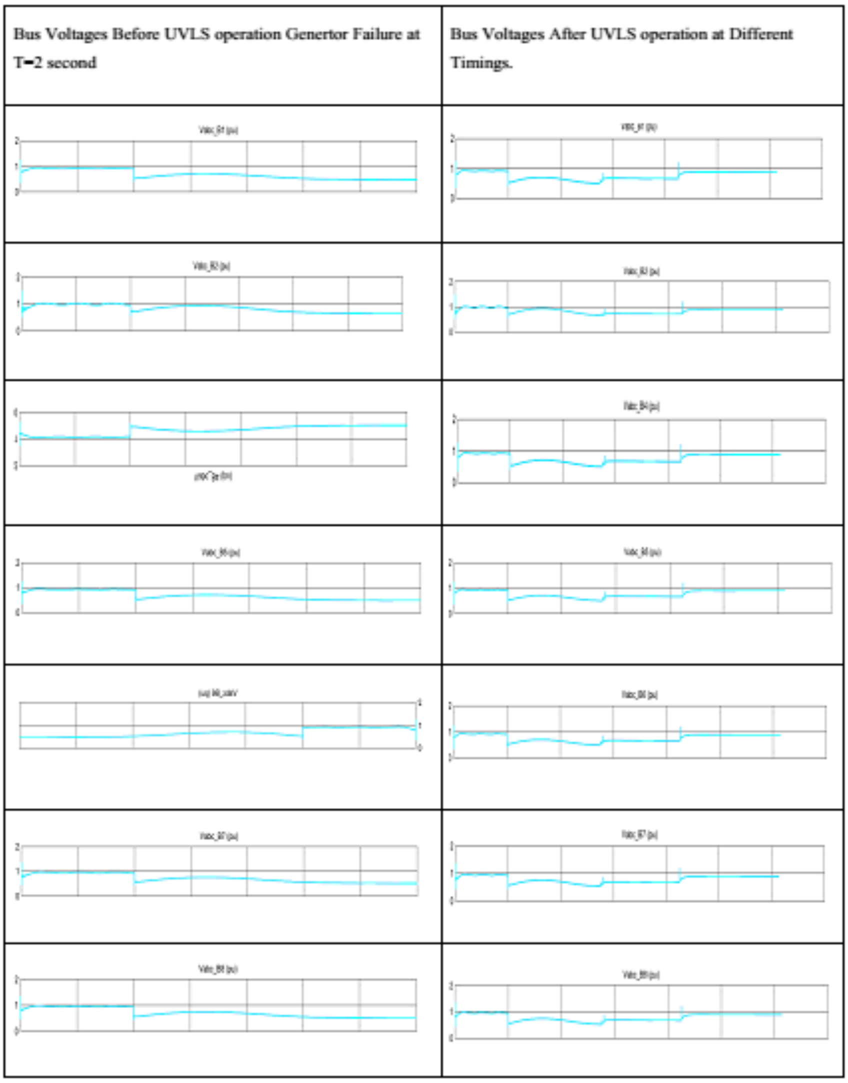

Figure 1.Voltage waveforms before and after UVLS operations

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6. CONCLUSIONS

Under voltage load shedding (UVLS) which is a low- cost mean of weakening system collapse plays a vital role in power system control when a system is subjected to a large disturbances Generator outage in this study .It has been employed for long time as the last remedy to prohibit major power system failure.

This paper comprehensively reviewed the UVLS schemes and simulation results clearly indicate the improvement in the voltage profile after trigger the UVLS scheme on week buses. More advance simulations and relay logic design is needed for further improvements.

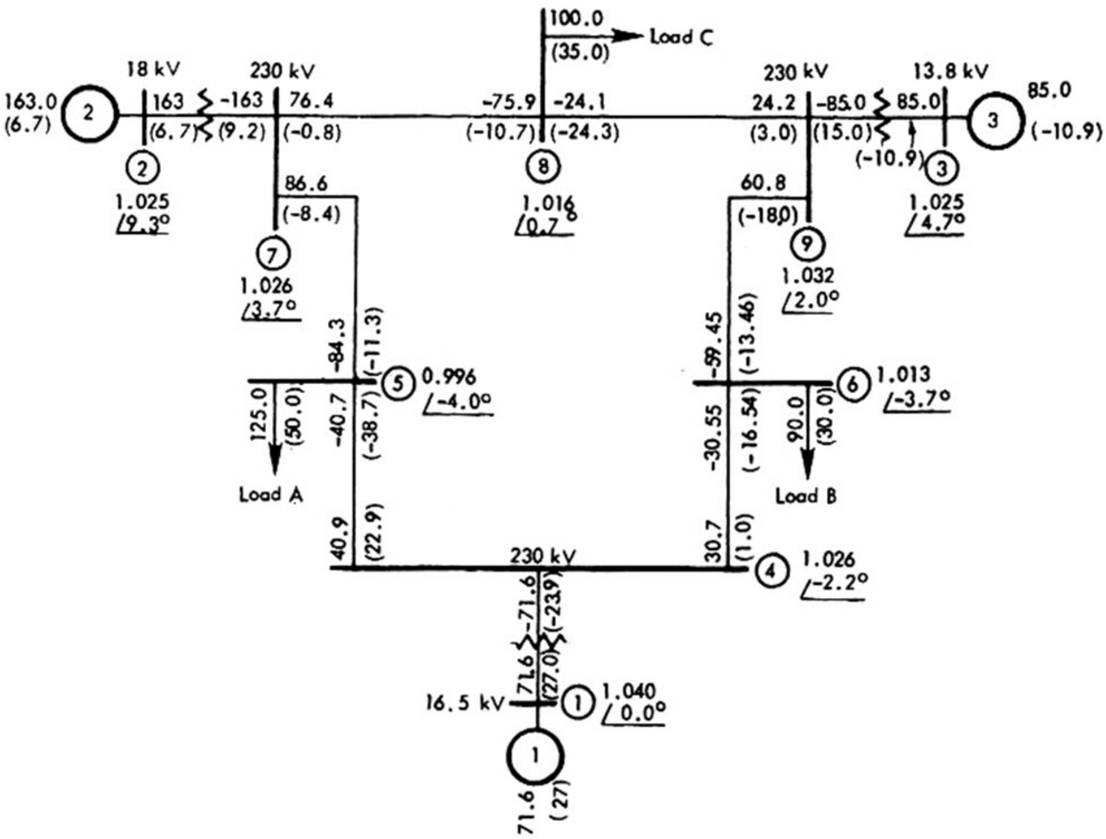

Figure 3. Single Line Diagram of WSCC 9 Bus test system..[25]

REFERENCES

[1] P. Kundur, J. Paserba, V. Ajjarapu, G. Andersson, A. Bose, C.Canizares, N. Hatziargyriou, D. Hill, A. Stankovic, C. Taylor, T. VanCutsem, and V. Vittal, "Definition and Classification of PowerSystemStability IEEE/CIGRE Joint Task Force on Stability Terms andDefinitions," IEEE Transactions on Power Systems, vol. 19, pp. 1387-1401, 2004

[2] C.W. Taylor, "Concepts of Under voltage Load Shedding for Voltage Stability," IEEE Trans. Power Delivery, Vol. 7, No. 2, pp. 480-488, Apr.1992.

[3] Under voltage Load Shedding Task Force (UVLSTF) Technical Studies Subcommittee, "Under voltage Load Shedding Guidelines," Western Systems Coordinating Council, July 1999.

[4] Charles Mozina “Under Voltage Load Shedding” Consultant ,Beckwith Electric Co.,Inc

[5] C.Moors, “On the Design of Load Shedding Schemes Against Voltage Instability in Electric Power Systems,”PhD Thesis University of Li’ege, Belgium,2003.

[6] H.G.Sarmiento,R.Castellanos,G Villa,and M.Mirabal “Revisting Undervoltage Load Shedding Schemes: A Step by Step Approach”Transmission and Distribution Conference and Exposition,2008

[7] T. Amaree,A.M Ranjbar,B Mozafari and N.Sadati, “An enhanced under voltage load shedding scheme to provide voltage stability”, Electric Power Syst.Res.,vol 77,2007,pp.1038-1046

[8] W.Xu and Y.Mansour “Voltage stability analysis using generic dynamic load models,” IEEE Transaction on Power Systems,vol.9,no.1,pp.479-486,February 1994.

[9] V.C. Nikolaidis,C.D. Vournas, “ Design Strategies for Load shedding Scheme Against Voltage Collapse in the Hellenic System,”IEEE Trans.Power Syst.Vol.23 No.2,pp.582-591,May 2008.

[10] B, Ingelsson,P.Lindstr”om, D. Karlsson. G. Runvik,J. Sj”odin, “Special Protection Scheme against Voltage Collapse in the South Part of the Swedish Grid,”Proc.CIGRE Conference ,1996,Paper no 38-103.

[11] D.Lefevre,T.Van Cutsem, “Undervoltage Loas Dhedding Scheme for the Hydro-Quebee System”,IEEE Power Engineering Society General Meeting,June 2004.

[12] G. Mevludin, T. Van Cutsem, “Adapative Wide area Closed –Loop Undervoltage Load Shedding Using Synchronized Measurements”power & Engineering Society GM 2010.

[13] Deuse, J., J. Dubois, R. Fanna, and I. Hamza. "EWR under voltage load shedding scheme." IEEE transactions on power systems 12, no. 4 (1997): 1446-1454.,November 1997.

[14] Balanathan R, Pahalawaththa NC, Annakkage UD. A strategy for undervoltage load shedding in power

systems. InPower System Technology, 1998. Proceedings. POWERCON'98. 1998 International Conference on 1998 Aug 18 (Vol. 2, pp. 1494-1498). IEEE.

[15] Kolluri, S., K. Tinnium, and M. Stephens. "Design and operating experience with fast acting load shedding scheme in the Entergy system to prevent voltage collapse." Power Engineering Society Winter Meeting, 2000. IEEE. Vol. 2. IEEE, 2000.

[16] Moors, Cedric, Daniel Lefebvre, and Thierry Van Cutsem. "Load shedding controllers against voltage instability: A comparison of designs." Power Tech Proceedings, 2001 IEEE Porto. Vol. 2. IEEE, 2001.

[17] B,Otomega,T.V.Cutsem,"Undervoltage Load Shedding Using Distributed Controllers,"IEEE Trans,Power Syst,.Vol.22 No.4 pp 1898-1907, Nov.2007

[18] Capitanescu, Florin, et al. "Decentralized tap changer blocking and load shedding against voltage instability: Prospective tests on the RTE system."International Journal of Electrical Power & Energy Systems 31.9 (2009): 570-576.

[19] Glavic, Mevludin, and Thierry Van Cutsem. "Wide-area detection of voltage instability from synchronized phasor measurements. Part I: Principle." IEEE Transactions on Power Systems 24.3 (2009): 1408-1416.

[20] Van Cutsem, Thierry, Cedric Moors, and Daniel Lefebvre. "Design of load shedding schemes against voltage instability using combinatorial optimization." Power Engineering Society Winter Meeting, 2002. IEEE. Vol. 2. IEEE, 2002.

[21] Gong, B., Pinheiro, A. and Hiskens, I., 2010, July. Optimal load shedding with the support of dynamic generation control in electric power systems. InIEEE PES General Meeting (pp. 1-6). IEEE.

[22] Moors, Cédric, and Thierry Van Cutsem. "Determination of optimal load shedding against voltage instability." Proc. 13th Power System Computation Conference (PSCC). 1999.

[23] Balanathan, R., N. C. Pahalawaththa, and U. D. Annakkage. "Undervoltage load shedding for induction motor dominant loads considering P, Q coupling."IEE Proceedings-Generation, Transmission and Distribution 146.4 (1999): 337-342.

[24] Otomega, Bogdan, and Thierry Van Cutsem. "Local vs. wide-area undervoltage load shedding in the presence of induction motor loads."PowerTech, 2009 IEEE Bucharest. IEEE, 2009.

[25] Anderson, P. M., A. A. Fouad, and H. H. Happ. "Power system control and stability." IEEE Transactions on Systems, Man, and Cybernetics 9.2 (1979): 103-103.