

Implementation of Under Voltage Load Shedding for Fault Induced Delayed Voltage Recovery Phenomenon Alleviation

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Abstract – Significant penetration of induction motor loads into residential neighborhood and commercial regions of local transmission systems at least partially determine a vulnerability to a fault induced delayed voltage recovery (FIDVR) event. Highly concentrated induction motor loads with constant torque could stall in response to low voltages associated with system faults. FIDVR is caused by wide spread stalling of small HVAC units (residential air conditioner) during transmission level faults. An under voltage load shedding scheme (UVLS) can be an effective component in a strategy to manage FIDVR risk and limit the any potential disturbance. Under Voltage Load Shedding take advantage of the plan to recovery the voltage of the system by shedding the load ways to alleviation FIDVR.

Keywords: Fault induced delayed voltage recovery, Under voltage load shedding, Stall phenomenon, Induction motor loads, Locked rotor current

1. Introduction

Recently abnormal weather such as heat waves, cold spells in the world. Air conditioning equipment supply rapidly increasing, the same time as the previous period when temperatures. Increase income and ease of the electricity equipment for energy efficient consumption increasingly. Base load demand the proportion of the industrial load is reduced but the proportion of general demand of the air conditioning load is increasing. And new housing developments, where air conditioning compressor motor load is considerably highly. Most heating, ventilation, and air conditioning (HVAC) units used by households and small business buildings are air conditioning units.

Induction motor loads constitute a major portion of loads in power systems. Gradual increase in the proportion of induction motor loads will cause a serious impact on the stability of the power systems. It appears necessary to account accurately for induction motor loads in dynamic and transient stability studies of power systems. It has been found that in the event of a system after the fault, the stalling behavior of induction motor loads may lead to delayed voltage recovery. Induction motor loads penetration is one of the most critical events that determine a transmission system's susceptibility to FIDVR (Fault Induced Delayed Voltage Recovery) phenomenon. Highly concentrated induction motor loads with constant torque

could stall in response to low voltages associated with system faults. [1-5]

One of the major goals of power system operating voltage stability is maintained. Short-term voltage stability a matter of FIDVR phenomenon has emerged as an important issue.

Fault Induced Delayed Voltage Recovery is the phenomenon whereby system voltage remains at significantly reduced levels for several seconds after a transmission fault has been cleared. The North American Electric Reliability Corporation (NERC) Transmission Issues Subcommittee provides the following definition for FIDVR in their recently published white paper. [2]

Fault Induced Delayed Voltage Recovery (FIDVR) – a voltage condition initiated by a fault and characterized by: [2]

- Stalling of induction motors.
- Initial voltage recovery after the clearing of a fault to less than 90% of pre-contingency voltage.
- Slow voltage recovery of more than 2 seconds to expected post-contingency steady state voltage levels.

This phenomenon is due to a low level voltage for a few seconds after the fault removal cause voltage instability and voltage collapse in the fastest time. The happening FIDVR is induction motor loads high concentration in the region after the fault. The kinetic energy of the motor loads, rapid increasingly consumption of the reactive power in the system according to the induction motor loads on the grid penetration.

After the fault, the higher the percentage of motor load, this will slow voltage recovery and the risk of spread to wide-area blackouts. The FIDVR phenomenon trend is the

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increasing air conditioning load is further increased the probability. The low voltage condition persists for a few seconds, the motor voltage cannot recovery quick and the motor begins to stalling. Motor loads stalling is the reactive power consumption dramatically increase of the voltage instability occurs. [1]

It has been mentioned several ways in order to reduce the effect of FIDVR. Voltage recovery characteristics that vary greatly depending on the fault clearing time of after the fault, there are ways to reduce the fault clearing time.

Considering the regional characteristics of the motor load proportion and the injection SVC and STATCOM in FIDVR occurs, reduces the effectiveness of the FIDVR. To quickly reset the relay operation time, the plan shall take into account the improvement of the performance of the equipment and protection coordination. It refers to the phenomenon of delayed voltage recovery after the fault by the induction motor load stall. Planning studies have not been able to simulate FIDVR events very accurately because of inaccurate modeling of loads. [2]

An under voltage load shedding scheme (UVLS) can be an effective component in a strategy to manage FIDVR risk and limit the any potential disturbance. UVLS is generally viewed as ineffective in preventing fast voltage collapse, quite effective in preventing voltage collapse. Under Voltage Load Shedding take advantage of the plan to recovery the voltage of the system by shedding the load ways to alleviate FIDVR.

In this paper, we proposed the ways to alleviate scheme for the delay voltage recovery by considering the proportion of induction motor loads in the actual system.

2. The Current UVLS Scheme in KEPCO System

The existing SPS applied to the KEPCO system has been designed to operate during extreme contingencies including the outage of one route 765kV double circuit lines in the load concentrated area. [9]

The operation process of existing SPS is as follows. If a contingency occurs, transmission line is dropped out within 5 cycles by protective relays that is operated at each end of the transmission line. The signal that detected by protective relay about contingency is transferred to the SCADA system in the KEPCO system. There are predefined 345kV pilot buses which are sensitive with variation of the voltage to monitoring low voltage bandwidth violation. If one of two 345kV pilot bus voltage is lower than 340kV (0.9885 p.u.) during 200 millisecond period, under voltage relays send the signal to the same SCADA system. If the SCADA system receives these two signals, in order to prevent voltage collapse, predetermined loads become shedding. The locations of shedding load are set by simulation results. Load shedding locations are selected among the location of UFLS (Under Frequency Load Shedding). Currently, load

shedding amount is set to about 1500MW, and it is shed whole amount at a time. [9]

The limitations of the current UVLS scheme for voltage instability applied to the power system is that it does not consider the induction motor loads. The proportion of induction motor loads is highly (50-60% of the entire system consumes reactive power), there are limitations in review ignored.

In the current scheme does not reflect the induction motor load. Also, induction motor stall phenomenon cause to FIDVR is not considered.

The characteristic of the ZIP model, the voltage decreased and the load decreased, alleviate the severity of the system. If the motor load is considered to reflect the load voltage recovery characteristics instability occurs. Voltage begins to drop gradually, and when a certain level to fall rapidly lead to system instability. Due to the characteristic of the motor load decreases, the voltage reactive power consumption increases. The voltage drop in the motor load has the load recovery characteristics. Progressively more reactive power is absorbed, the more voltage drop indicates the instability eventually causes the voltage. And selection of low-maintenance time is a very difficult problem. Low-maintenance time should be selected through the dynamic analysis noted.

Long-term dynamics into consideration when performing induction motor loads, OXL, ULTC and so on. Review the ZIP load model by applying the dynamics common to the grid to be stable. In the case of static analysis, constant power load model is unstable because after the fault, the limit point of the grid is determined.

Load modeling is most important factor to calculate amount of load shedding. Because of limited information, it is very difficult that select proper load model and load parameter. If proper load model is selected, it is possible that sets minimum amount of load shedding. Statistics can be used to select load model and load parameter. Ministry of Knowledge Economy announce first time the "power consumption map of the country" that contain 227 municipalities. [16]

3. FIDVR Phenomenon

3.1 A typical of FIDVR phenomenon

Heavily loaded transmission lines during low voltage conditions can result in operation of protective relays causing some transmission lines to trip in a cascading mode. Following fault clearing with transmission outages, motor loads draw very high current while simultaneously attempting to reaccelerate, thereby making delayed the voltage recovery process. While trying to recover, if the voltage drops to a very low point for a sustained duration due to system's inability to provide reactive support, some motors may stall. Such radical stalling of motor further

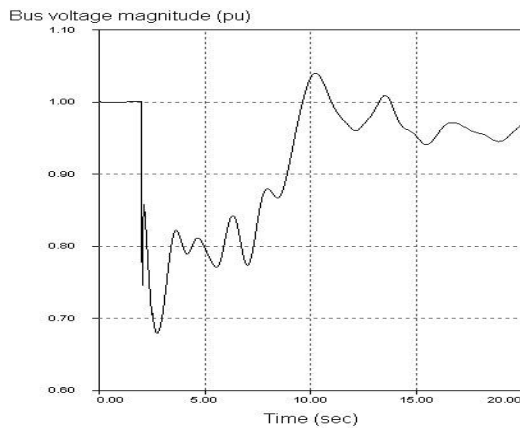


Fig. 1. FIDVR phenomenon

exacerbates the conditions by increasing the reactive power requirements quickly. Massive loss of load and possibly area instability and voltage collapse may follow. [6]

A fault induced delayed voltage recovery phenomenon following a disturbance is indicated in Fig. 1.

3.2 Stalled induction motor loads

It breaks utility loads into the following three distinct customer classes: residential, commercial, and industrial. For each of these customer classes, the load is broken into the three different categories. Percentages are given for each of these categories as to how much of the load belongs in each of the categories. The motor loads are broken into large and small motors. The large motor is meant to typically model industrial motors while the small motors is meant to typical model residential motors; thus, air conditioners. [10]

Induction motor loads can be divided into large HVAC units (large inertia motor loads) and small HVAC units (small inertia motor loads). Large HVAC units tend to maintain their speed during short periods of reduced voltage. And primarily associated with commercial or industrial cooling, are usually equipped with under voltage relays that can remove the motors from the system within 6 cycles. This is caused by our stall before the stall due to high inertia exists, but weakly affects the stall. On the other hand, small HVAC units tend to lose their speed rapidly as a result of reduced voltage and to stall when the voltage is reduced below 60% for 5 cycles or longer. Small HVAC units may not have protection that will trip the unit off before stalling occurs. Small HVAC units are equipped with thermal overcurrent characteristic relays, which are much slower than under voltage relays and operate in the second time frame. These thermal overcurrent relays display the inverse time characteristics. [1]

FIDVR is caused by wide spread stalling of small HVAC units (residential air conditioner) during transmission level faults. Low inertia to cause a stall, small residential air conditioner or refrigerator motor is induction motor loads

are used in this belong.

3.3 Locked-rotor current condition

These induction motor loads are sometimes referred to as 'stall-prone' induction motors and the stalled condition is sometimes referred to as a locked rotor condition. Stalled induction motor loads require approximately 5 to 6 times their steady state operating current during locked rotor current conditions. However, the increased current at low voltage conditions may not start the motor, that is, the rotor will not be released from the locked rotor current condition.

The heavy locked rotor current demands on the power systems result in voltage remaining significantly depressed for a period of time, typically a few seconds, after the fault is cleared, thereby leading to a first cascading effect. Cascading voltages collapse adjacent portions of the interconnected power systems that may extend further through the utility power grid. A second cascading effect includes a response to the reactive power demands on the electric power generators coupled to that portion of the power systems. If voltages stay depressed long enough, the associated generators trip or, alternatively, OXL (over excitation limiting) devices limit and/or reduce reactive power generation, thereby facilitating further voltage reductions and a possible system wide voltage collapse. A third cascading effect includes the stalled induction motors drawing the increased current such that they are removed from service by thermal protection devices with an inverse time current characteristic that is usually set for 3~20 seconds. The combined effect of larger induction motor loads and smaller induction motors tripping over such a short period of time may result in significant load loss, as can the loss of generation described above, with a potential effect of a voltage recovery overshoot inducing a high voltage condition. [3]

3.4 Load modeling

In power systems steady state analysis, load model assumes constant power load due to of the systems uncertainty. Loads are configuration by constant power, constant impedance, constant admittance, and induction motor load. Induction motor loads high concentration in the area, these areas should be disconnected for voltage stability about disturbance. Appropriate induction motor modeling is necessary to understand induction motor characteristics. Induction motor loads generally affect the voltage recovery process after voltage sag has been incepted due to system faults, and in many occasions due to extended voltage sag secondary effects such as stalling or tripping of sensitive motors might happen leading to massive load disruption. So, it is very vital to represent large, small and trip induction motor loads in various combinations in the system, so that we capture the stalling phenomenon of induction motor load, the real and reactive

power requirements in the stalled state, and the tripping caused by thermal protection. The induction motor load must be modeled such that it is sensitive to dynamic variations in voltage and frequency, and emulates the typical characteristic of consuming more power at increased speeds.

3.4.1 ZIP load model

The most commonly used static load model is the ZIP model. The ZIP model is a polynomial load model expressed by a summation of exponential models that represent constant impedance (Z), constant current (I), and constant power (P) loads. The ZIP model is represented the power relationship to voltage magnitude as a polynomial equation, usually in the following from [1]:

$$\begin{aligned} P_L &= P_0 \left[p_1 \left(\frac{V}{V_0} \right)^2 + p_2 \left(\frac{V}{V_0} \right)^1 + p_3 \right] \\ Q_L &= Q_0 \left[q_1 \left(\frac{V}{V_0} \right)^2 + q_2 \left(\frac{V}{V_0} \right)^1 + q_3 \right] \end{aligned} \quad (1)$$

Where p_1, q_1 are constant impedance load parameters, p_2, q_2 are constant current load parameters, and p_3, q_3 are constant power load parameters. And $p_1 + p_2 + p_3 = 1$, $q_1 + q_2 + q_3 = 1$ when $V = V_0$. ZIP model can, depending on the coefficients, represent the constant impedance, the constant current load and the constant MVA load.

3.4.2 CIM5 load model

The CIM5 models can be used to model either single-cage or double-cage induction motors including rotor flux dynamics. The motor is modeled in the power flow as a bus load where the entire load at a specific load id is taken as the steady-state motor load. These models may be applied to an individual load or a subsystem of loads. For example, the CIM5 model can be applied to a specific load in order to model a specific induction motor. The CIM5 model can be applied to all loads in a specific area in order to model generic motor load using typical data. The load composition can be any percentage of constant MVA, constant current or constant admittance. The data input for the model are the equivalent circuit impedances for either a Type 1 or a Type 2 equivalent circuit model. [15]

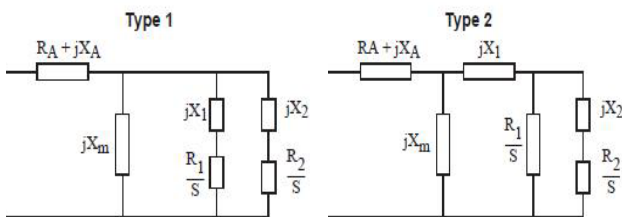


Fig. 2. Type 1, 2 used in CIM5 models in PSS/E

Table 1. Induction motor parameter

Parameters	Value
Stator resistance (Rs)	0.078
Stator reactance (Xs)	0.065
Rotor resistance (Rr)	0.044
Rotor reactance (Xr)	0.049
Magnetizing reactance (Xm)	2.67
Inertia Constant (H)	0.5

The only difference between the two types is where the first rotor inductance is placed on a parallel circuit, or series circuit, with the second rotor inductance for a double-cage machine. If a single-cage induction motor is used for analysis, X2 and R2 are set to 0 and the machine type can be neglected. The CIM5 induction motors fully model rotor transient, making them third-order induction machine models, and CIM5 can model online, or offline, motor starting. [15]

Table 1, shows the induction motor parameter. The following are sample data for induction motor equivalents representing small induction motor load. [17]

CIM5 load model this set of parameters can represent the stalling process of induction motor load responding to system disturbances on the whole.

Eq. (2) shows the CIM5 type models use the following equation as its representation for mechanical load torque (Tload). [6-7]

$$T_{load} = T_{nom} (1 + \Delta\omega)^D \quad (2)$$

Where $\Delta\omega$ is the motor speed deviation from nominal (per unit slip), D is the load damping factor. And the motor load torque at synchronous speed (Tnom). These CIM5 models use the more conventional torque equation where Tnom is the initialized load torque. Tnom is initialized by setting the polynomial component equal to one during initialization. At initialization, the CIM5 type models pick up the total power for the specified load id at the bus and together with the equivalent circuit data and the bus voltage, calculates the initial slip and reactive power consumption of the motor. The models include a relay that can be used to trip the motor for an under voltage condition. [7]

3.5 Induction motor load modeling

Induction motor load model could be tripped off because of under voltage protection, motor speed deviation is little or great when disturbance occurrence. So the induction motor load model with tuned parameters will be employed for simulation of the problem on the delayed voltage recovery and motor stalling, during and after the fault.

The main causing the delayed voltage recovery is stalling behavior of induction motor loads. To understand the delayed voltage recovery phenomena, reasonable induction motor load model should be developed. This

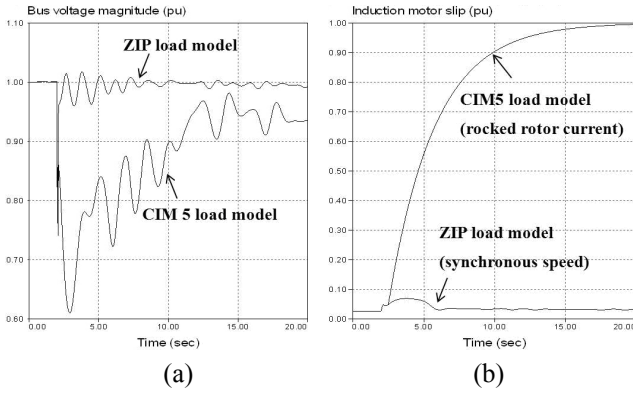


Fig. 3. ZIP load model and CIM5 load model: (a) Bus voltage magnitude; (b) Induction motor slip

section will give the induction motor load model used in PSS/E and turn the parameters according to severe disturbance scenarios. The PSS/E CIM5 load model with this set of parameters can represent the stalling process of induction motor loads responding to system disturbances on the whole. For the transient study, dynamic models for generators, exciter, governor systems, and appropriate load models are used. Loads in the concentrate area were partitioned as different proportion induction motor load (dynamic) and ZIP load (static). [6-8]

Fig. 3 shows the load model comparing two common assumptions of ZIP load modeling versus the short-term voltage stability CIM5 load modeling. With ZIP loads modeled, there is no collapse or slow voltage recovery shown, CIM5 load modeling, a voltage collapse event is a real possibility. The PSS/E CIM5 model does meet the short-term voltage stability modeling need. The CIM5 load model simulates a motor's electromagnetics and also its rotor load dynamics. The model is a motor's transient component that is zero at steady state, but for non-steady state conditions, it changes the rotor flux linkages when the motor experiences changes in voltage. [10, 15]

When the ZIP load model, a three phase fault applied at 2 seconds with the fault and cleared 5 cycles later. The voltage recovers very quickly after the fault clears. In contrast, when the CIM5 load model, the instant voltage drops and the locked rotor current is represented. This simplification produces a worse case result since locked rotor current is the largest current drawn by a stalled induction motor. An induction motor slip value of 1 is locked rotor current condition, induction motor slip value of 0 is synchronous speed condition.

For transient stability analysis of voltage, accurate load model is important. However, there are difficulties to be accurate load model for nonlinearity and time variation of the load. In this paper, we take advantage of the model plus the induction motor model to overcome the limitations of static load models used in transient stability analysis of existing using data from real strains. It is possible to use the induction motor model can be used to better reflect the

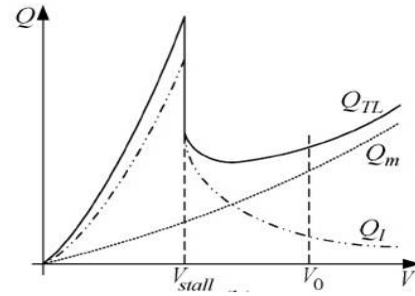


Fig. 4. Q-V characteristics of induction motor load [8]

dynamic characteristics of the load, which actually exists, physical characteristics are also reflected.

3.6 Q-V characteristics of induction motor load

Modeling of induction motor appropriate machine modeling is necessary to understand induction motor characteristics.

It can be proved that the motor stable operating region is to the left of the peak in Fig. 4, and as functions of voltage. Gradually increases as voltage decreases until, where is increased greatly. Observing curve, it is found: 1) when voltage is close to the rated value, slope of the curve is positive (voltage decrease causes reduced reactive power demand); 2) curve between rated voltage and stalling voltage is relatively flat (low voltage sensitivity); 3) when voltage is reduced beyond the stalling value, reactive power demand is increased tremendously to a very large value. Q_l is reactive power by mechanical load, Q_m and Q_{TL} represent reactive power by magnetizing reactance and total load. [8]

Consumed reactive power loads and voltage have the following relationships. When the voltage approaches the stall voltage reactive power consumption increases significantly, to maintain the characteristics of the induction motor load. In the Fig. 4 shows, the rated voltage and the bus voltage is closer, that the consumption of reactive power load characteristic is similar to the constant power. Voltage decreases and the slope decreased, but the slope is very small so the characteristic is similar to constant power. But the bus voltage drops below a certain level, the motor drops to near stall voltage reactive power consumed by the load is increased exponentially. If you are a serious failure of the system, depending on the voltage decreased. Depending on the characteristics of the motor load reactive power, resulting in a significant increase in load causes system voltage instability.

4. Evaluate the Voltage Response of Induction Motor Loads

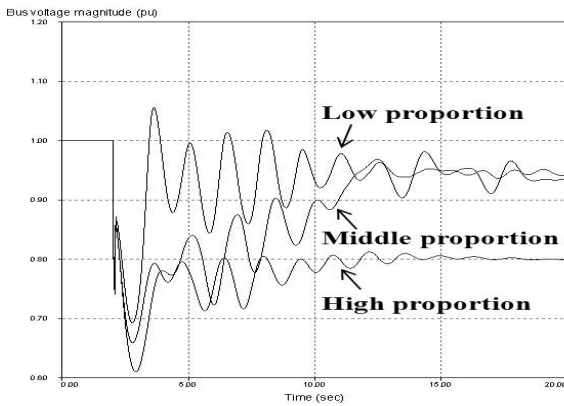
In this section, evaluate the voltage recovery response of

the induction motor load model under several different scenarios. This simulation result demonstrates that the same type of fault with different proportion of induction motor loads can result in dramatically different voltage stability problem. The dynamic models of induction motor loads were further split equally into three different proportions: i.e., considering at a high proportion, considering at a middle proportion, and considering at a low proportion. The fault at 2 sec consists of the voltage changes caused by the occurrence of an emergency. [1]

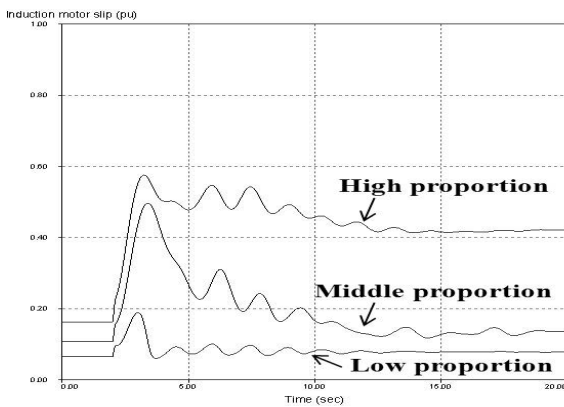
And the evaluate voltage response of induction motor loads was performed the simulation can be summarized as follows:

- Low proportion induction motor loads on the total loads: 40%
- Middle proportion induction motor loads on the total loads: 50%
- High proportion Induction motor loads on the total loads: 60%

The loads except induction motor loads were applied by constant current model about active power loads and constant impedance model about reactive power loads.



(a)



(b)

Fig. 5. Voltage recovery by induction motor loads with different proportions: (a) Bus voltage magnitude; (b) Induction motor slip

Fig. 5 shows the considering at a low proportion has the highest voltage, while the others lower voltage and delayed voltage recovery during the stalled condition. It indicates that the more the proportion motor loads, the delayed voltage recovery process. And then, in this simulation, the slip of induction motor model continuously increases after fault clearing and stops at last. Considering at a high proportion has the highest slip, while the others lower slip condition. The proportion of the motor load increases, voltage is lowered and a longer start-up time of the motor may damage the motor. To increase the rotor of the motor output torque arising from this should be larger. Increasing the load on the output of the induction motor slip increases.

5. Implementation UVLS Scheme for FIDVR Phenomenon Alleviation

In this paper, evaluate the voltage response of induction motor loads with under voltage load shedding, the dynamic behaviors with the severe fault but different proportion of induction motor loads.

The simulation can be summarized as follows:

- Load shedding observed before and after the voltage recovery;
- Initial voltage recovery after the clearing of a fault to less than 90 percent of pre-contingency voltage;
- Voltage recovery after the fault, a delay of more than several seconds when the phenomenon is FIDVR;
- Induction motor stall: Q-V characteristic curve observed, stall area less than 0.7 [pu].

With appropriate modeling of induction motor dynamics, time domain simulations were run for the severe contingency. The contingencies lead to a fault induced delayed voltage recovery due to the presence of induction motor loads. The buses having delayed voltage recovery problem under severe contingency was made.

The following shows the assumed voltage instability scenario and reviews the appropriate implementation of the procedures of UVLS scheme.

Table 2. Voltage instability scenario

Time(sec)	Scenario
2.0000	765kV transmission line fault Disconnect shunt reactor
2.0833	Clear line fault
2.1500	Disconnect generator

Table 3. Procedure of UVLS scheme

Step	Procedure
Step 1	Simulation time (20 sec)
Step 2	Initial voltage recovery after the clearing of a fault to less than 90 percent of pre-contingency voltage
Step 3	Load shedding at 2.5 sec
Step 4	Observation of the bus voltage magnitude

Numerous variations in proportion induction motor load have been considered. We found that the alleviated fault induced delayed voltage recovery process as shown in Fig. 6. In Fig. 6 are shown simulated voltage recovery time plots at three different cases and implementation UVLS scheme for FIDVR phenomenon mitigation.

Implementation UVLS scheme for FIDVR mitigation,

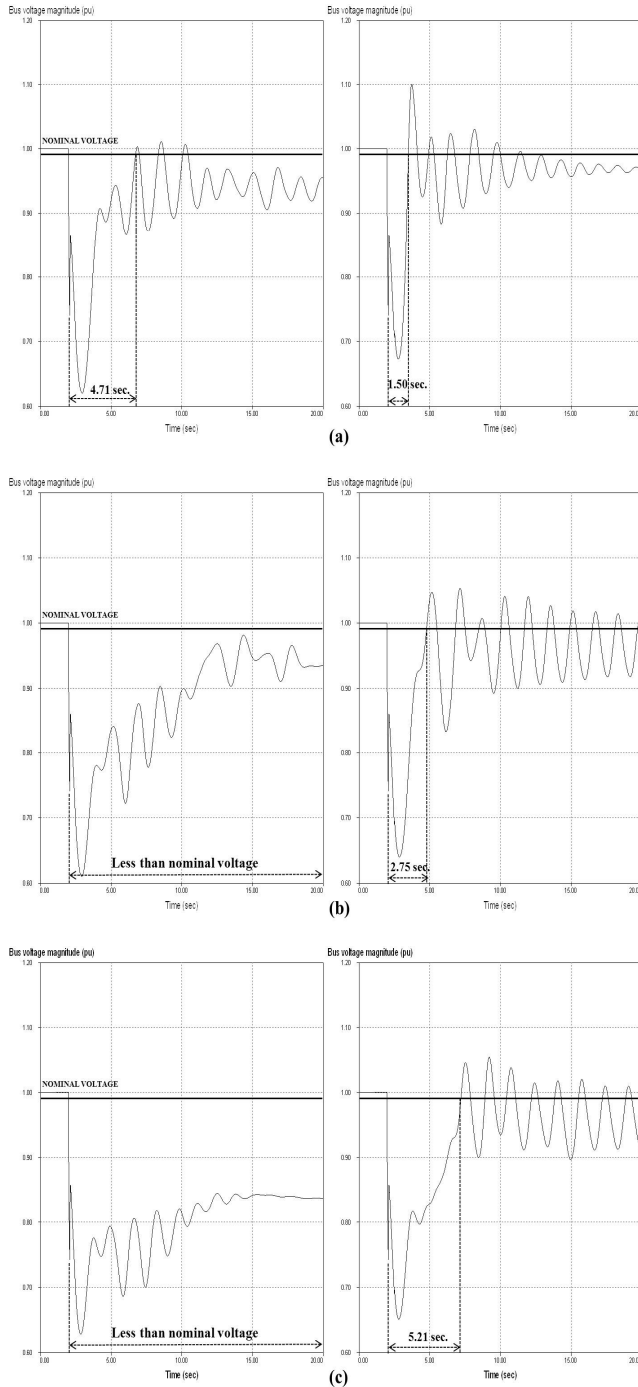


Fig. 6. Implementation UVLS scheme for FIDVR mitigation: (a) Considering at a low proportion; (b) Considering at a middle proportion; (c) Considering at a high proportion.

load shedding was done 0.5 sec after the occurrence of the emergency. The under voltage load shedding scheme shows the voltage magnitude results after the emergency. When the voltage is reduced to a certain value, the motors will be disconnected from the grid.

After UVLS operation, the reduction in voltage recovery time can be observed. Any action taken quickly will have a more beneficial effect and could lead to an overall

Table 4. Recovery time with and without UVLS

Proportion	Recovery time (Without load shedding)	Recovery time (With load shedding)
Low	4.71 sec	1.50 sec
Middle	Less than nominal voltage	2.75 sec
High	Less than nominal voltage	5.21 sec

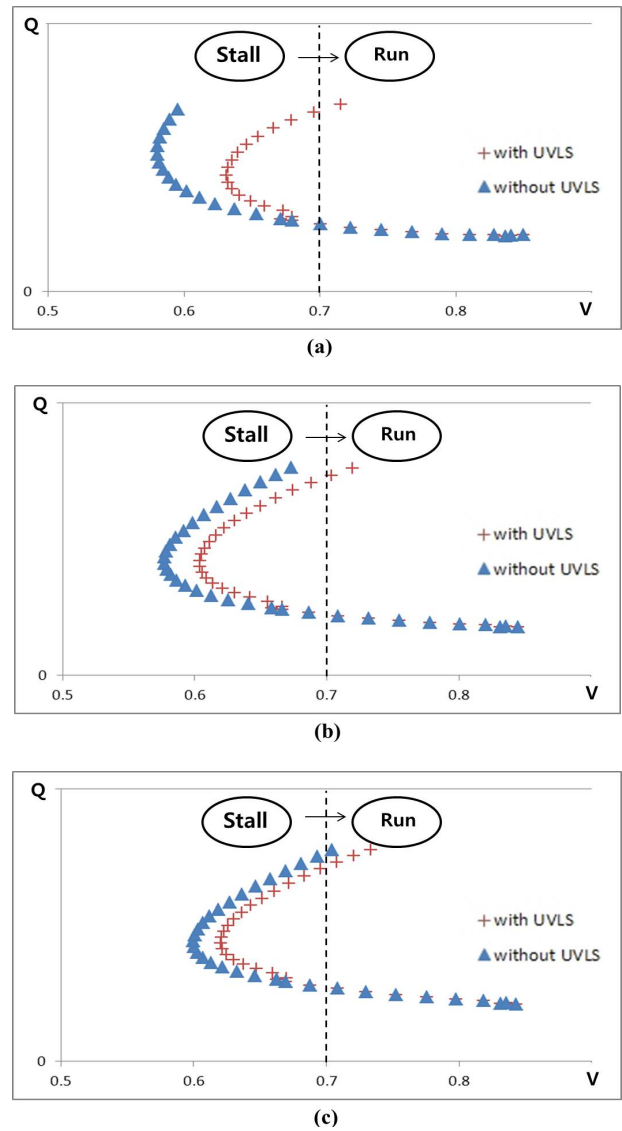


Fig. 7. Q-V characteristic curve with and without UVLS: (a) Considering at a low proportion; (b) Considering at a middle proportion; (c) Considering at a high proportion.

reduction in the delayed voltage recovery time of UVLS required.

Implementation UVLS scheme for FIDVR mitigation, load shedding was done 0.5 sec after the occurrence of the emergency. Steady state was attained 0.5 sec after the emergency. The under voltage load shedding scheme shows the voltage magnitude results after the emergency. When the voltage is reduced to a certain value, the motors will be disconnected from the grid.

After UVLS operation, the reduction in voltage recovery time can be observed. Any action taken quickly will have a more beneficial effect and could lead to an overall reduction in the delayed voltage recovery time of UVLS required.

And Table 4 shows the recovery time with and without UVLS results under severe contingency. The effectiveness of the UVLS scheme was demonstrated through different proportion of induction motor load case studies.

In Fig. 7 are shown simulated Q-V characteristic curve observed plots at three different cases and implementation UVLS scheme for FIDVR phenomenon mitigation. Mechanical characteristic of induction motor load cause stall phenomenon occurs. In this paper, we observed the Q_i curve, Q_i is reactive power by mechanical load. And Q_i curve is observed with and without UVLS operation.

Induction motor stall area, generally the voltage 0.7 [pu] below. Considering the induction motor load stall occurred in the case that can be observed. After UVLS operation, the Q-V characteristic curve in the stall area, go to run area can be observed. We found that the alleviated fault induced delayed voltage recovery process as shown in Fig. 7.

6. Conclusion

This paper has proposed the UVLS schemes can be used against severe emergencies to alleviation FIDVR. When the stalled induction motor loads enter the stalled condition, they will draw on considerable reactive power. The “sustained” increase in reactive power demand tends to delayed voltage recovery and can even cause voltage collapse in certain situations. When the stalled motors are tripped from the grid, the voltage will enter the delayed recovery condition. The more the stalled motors load, delayed the voltage recovery time. When voltage instability occurred, load shedding was implemented. The voltage recovery response is a very important dynamic characteristic of load behaviors. The ability of different proportion of induction motor loads to capture the fault induced delayed voltage recovery time is evaluated in this paper. It is also demonstrated that the severe the fault, implementation UVLS has reduced the voltage recovery time. Future works on the implementation of synchrophasor measurement units (PMUs), high sampling measurement devices, in recent years have enable utilities to recorded FIDVR events in the grid, especially in areas

supplying heavy a/c motor loads.

Acknowledgements

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