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Research Paper

Effect of Repetitive voltage Sag on Contactor Behavior

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Abstract

Contactor is one of device used in many industries which it is as connector between electric motor and source voltage. It is identified as susceptible device against voltage sag. In distribution system, repetitive voltage sag occurred due to operate automatically of re-closer to open and reclosing when fault. This study is to investigate effect of repetitive voltage sags on contactor behavior under distinct POW. Difference of voltage sag duration in first sag was applied to second sag in various POW of 0^o, 45^o, and 90^o. Time difference between first and second sags occurrence is 500ms and fixed, it is according to time delay range of operation re-closer. Time required of contactor's contact to open under distinct the POW are observed. The contactor is faster to drop out in the second sag compared with first sag when it was applied by repetitive voltage sag with 0^o POW. Otherwise the contactor to drop out in the second sag is longer than first sag when it was applied repetitive voltage sag under 90^o POW of sag initiation. Effect of voltage sag with 45^o POW causes the contactor to release it contact in similar duration time.

Keywords: *Contactor behavior, repetitive voltage sag, point on wave, current waveform*

1. Introduction

Effects of voltage sag on equipment still continue doing to study. It is due to several of voltage sag characteristics significantly influence on performance equipment[1]. Sag magnitude and duration as the primary characteristic. According to [2] voltage sag is reduced voltage in magnitude from 90% to10% of nominal voltage with sag duration from 0.5cycles until one minute. Phase angle of the sinusoidal voltage which the voltage sag starting occured is mentioned point on wave (POW) of sag initiation.

Primary distribution lines are often completed by re-closers to serve both urban and rural customer. It needs to protection systems against instantaneous or separate fixed faults. The purpose is to minimize the amount of exposure on the substation equipment [3]–[5].

Re-closer operates automatically to open and reclosing when fault occurs. Application re-closers can be adjusted for a number of some combination distinct operations namely for opening and automatic reclosing. A time delay of interval reclosing from 0.5 seconds until 2 seconds. Automatic reclosing is necessary for giving protection in line distribution systems by reason of it can clear instantaneous faults, which it can reach around 80% of the all outages [6]. On other hand automatic reclosing of distribution protection system can cause repetitive voltage sag.

Previous studies about influence of voltage sag on contactor performance have been presented in [7] which is the study consider effect of sag magnitude and sag duration on drop off time. Effect of POW on contactors has been carried out in [8] by simulation model and in [9] studied through experimental. Both in those studies show that difference POW of sag initiation has significant effect against the contactor time to drop out. Research repetitive of voltage sag on contactor has been documented in [6] and the result was presented in sensitivity curve by considering sag magnitude and duration.

This paper discuses effect of repetitive voltage sag on contactor take into account POW through experimental. Contactor behaviors for tripping is indicated by current waveform that flowing through in contactor coil. Time required of contactor's contact to open under distinct the POW are observed.

2. Contactor

Contactor are widely used in many industries which it functions is to give connection between motor and voltage source. It also has been identified as susceptible device against voltage sag. The contactors consist of primary and auxiliary contacts. The primary contact can disconnected if it is supplied by voltage sags. Schematic diagram of an AC contactor is presented in Fig. 1 [10].

When the winding coil of contactor get voltage supply, current flows in the coil will induce magnetic field to armature and spring pulled to close contact. The minimum magnetic force needed according to [7] such as equation (1). The force is influenced by voltage supply magnitude that connected to magnetic coil.

$$F_{min} = \phi^2_{\min} / 2\,\mu_o A \qquad (1)$$

where

μ_o : Air permeability,

A :Cross sectional area of the electromagnetic pole

$\phi_{\min}$:Minimum flux needed to prevent the electromagnet from disengaging.

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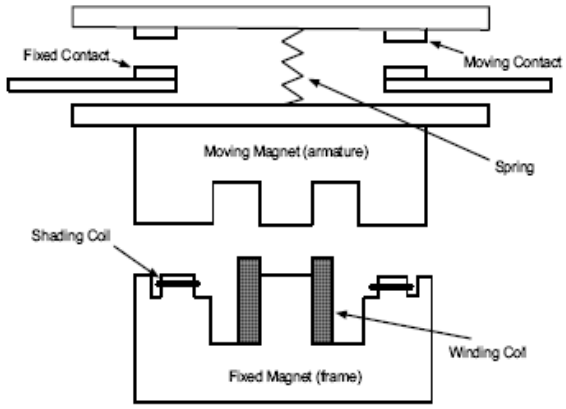


Fig.1: Schematic diagram of AC contactor

3. Test Apparatus and Method

A. Test Apparatus

An AC contactor of 20A, 240Volt is directly connected to a voltage sag generator (VSG). A 0.5HP, 240V single phase induction motor was used as load and an incandescent lamp of 25W was used as indicator which it will off when the contactor drop out. The test circuit is shown as in Fig. 2. The circuit is arranged without push button in order the contactor's contact reclose/restart to retest when the source voltage recover to normal.

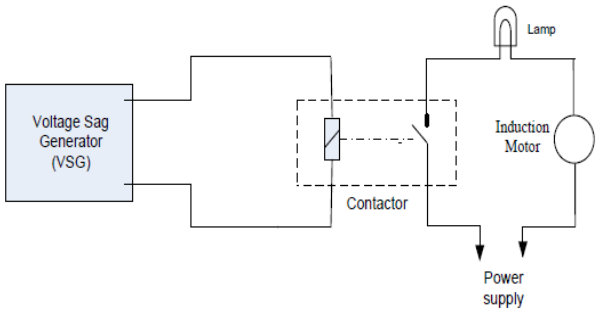


Fig.2: Test circuit of contactor

The VSG is one of facility found on equipment Schaffner Profline2100 Electromagnetic Compability. Many various power qualities can be produced by this equipment, for example; voltage sag, swell, harmonics, flicker, etc. Photo of the VSG is shown in Fig. 3.Testcontactor has been carried out on CERE laboratory in Universiti Malaysia Perlis (UniMAP).

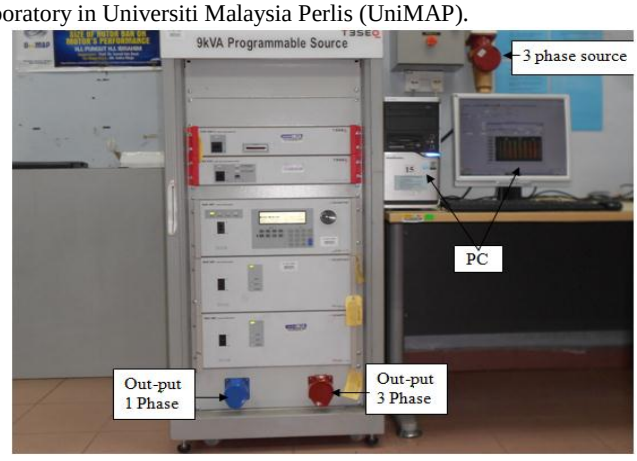


Fig.3: Photo of VSG

B. Testing Method

Testing has been conducted by using voltage sag characteristics which are magnitude and duration of voltage sag and POW. Investigation aims is to study effects of repetitive voltage sag on contactor behavior under three POWs of 0^o, 45^o and 90^o.

Fig. 4 shows the procedure testing of repetitive voltage sag on contactor with 500ms fixed time delay. The value is interval reclosing a time delay of auto re-closer i.e 0.5 to 2 seconds [6].

Difference time of the automatic reclosing is used as sag duration in first sag, t_1i.e. 50ms, 100ms, 150ms and the second sag duration, t_2 is 50ms fixed. Time required by contactor's contact to open in the second sag is observed.

The voltage sag supplied in the first sag magnitude, V1 and second sag magnitude, V2 is same and constantnamely 40% of the nominal voltage. This value is the threshold voltage value of contactor A for tripping [9].

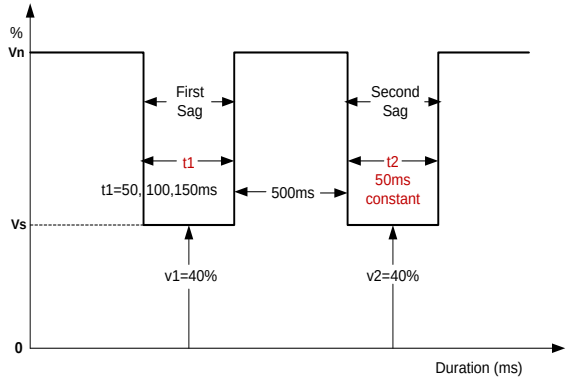
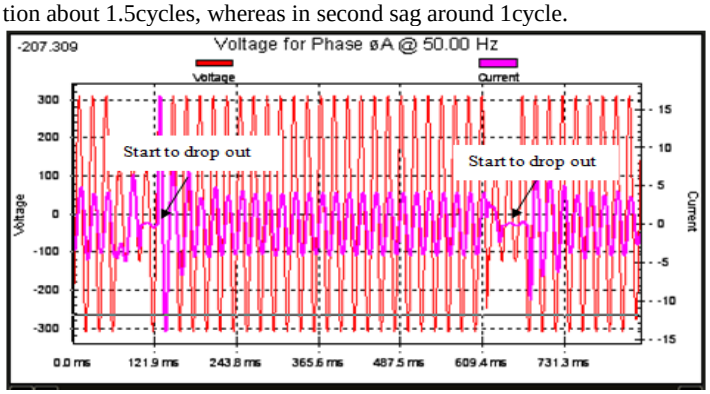


Fig.4: Test method of repetitive voltage sag on contactor

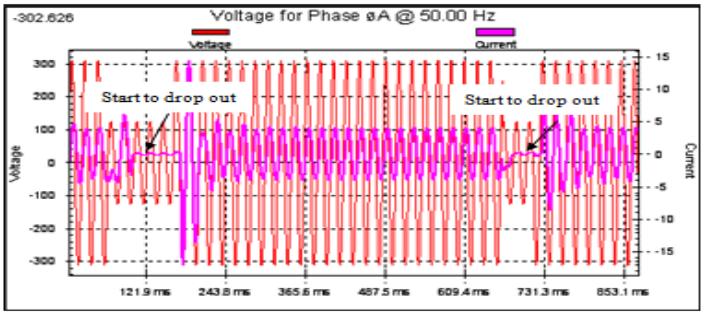
4. Results and Discussion

Testing results of repetitive voltage sags under distinct the POW of voltage sag initiation are shown through in Figs. 5 to 7 which is the contactor in drop out condition. The contactor is not directly drop out when it was supplied by the voltage sag and it needs few cycles. The contactor drop outis Indicated by current zero crossing and it means contactor's contact in condition opened. In the Figures is designated by sign arrow.

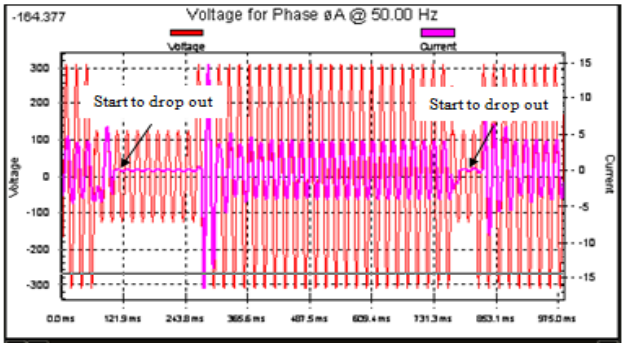
Figs. 5(a) to (c) show the contactor was applied by POW of 0^o under distinct sag duration in first sag. It can be seen that the time need by contactor to drop out in first sag for all sags duration about 1.5cycles, whereas in second sag around 1cycle.



(a) for $v_1 = v_2 = 40\%$, $t_1 = t_2 = 50$ms



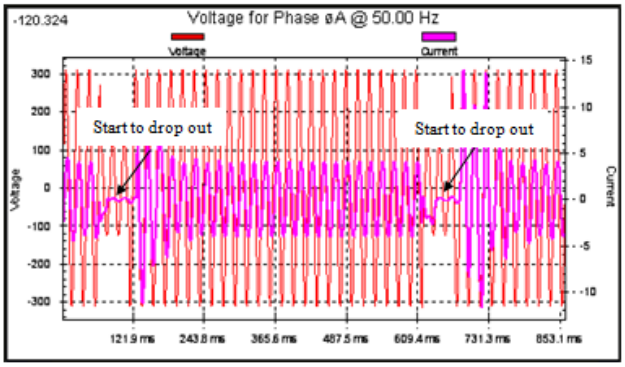
(b) for $v_1 = v_2 = 40\%$, $t_1 = 100$ms; $t_2 = 50$ms



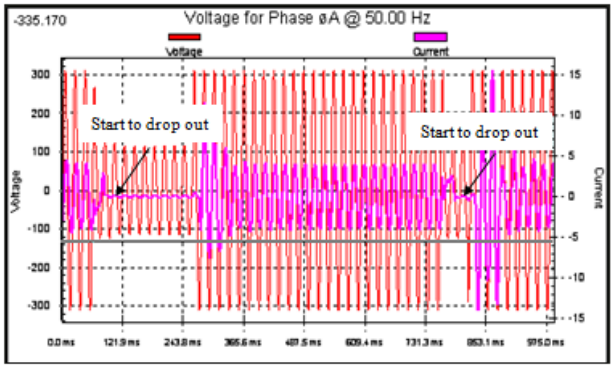
(c) for $v_1 = v_2 = 40\%, t_1 = 150ms; t_2 = 50ms$

Fig.5: The contactor behavior under 0^o POW

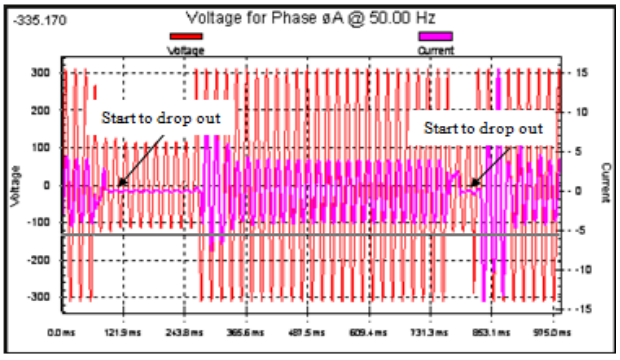
For 45^o POW, time duration of contactor to drop out in first and second sags is same such as in Figs. 6 (a) to (c). Therefore, there is no time difference between first and second sags on contactor to drop out; even though sag duration is applied on first sag is not same. Therefore, The POW is not influenced on the time duration.



(a) for $v_1 = v_2 = 40\%$, $t_1 = t_2 = 50ms$



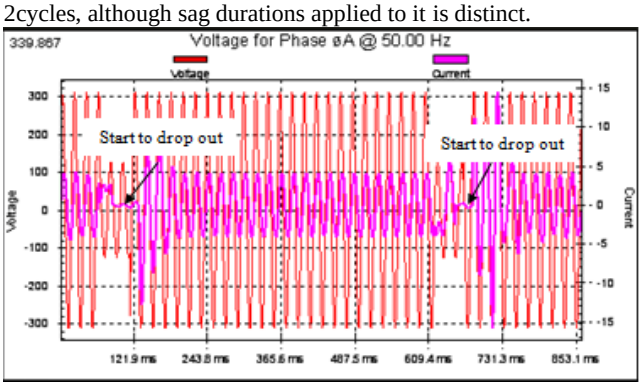
(b) for $v_1 = v_2 = 40\%$, $t_1 = 100ms; t_2 = 50ms$



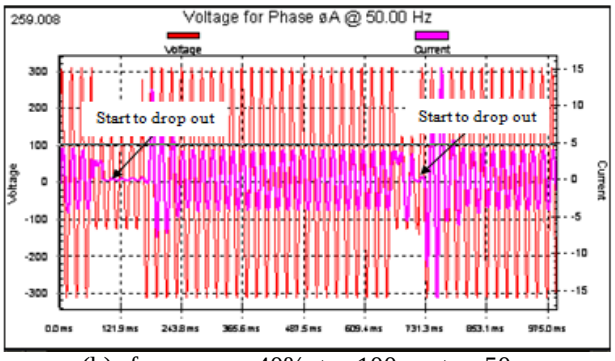
(c) for $v_1 = v_2 = 40\%$, $t_1 = 150ms; t_2 = 50ms$

Fig.6: The contactor behavior under45^o POW

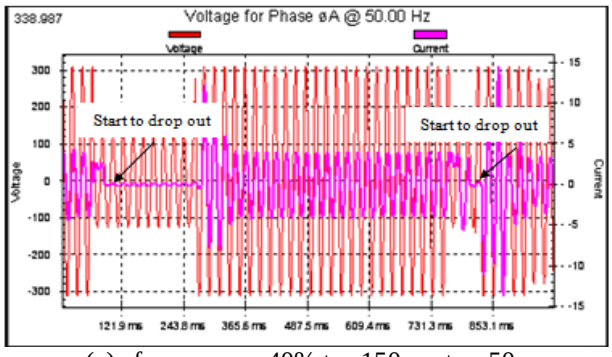
Figs. 7(a) to (c) present the contactor drop out in first and second sags under POW of 90^o. It can be observed that time duration need by the contactor to drop is fixed. For the first sag, it drops out around 1.5cycles whereas for second sag around 2cycles, although sag durations applied to it is distinct.



(a) for $v_1 = v_2 = 40\%$, $t_1 = t_2 = 50ms$



(b) for $v_1 = v_2 = 40\%$, $t_1 = 100ms; t_2 = 50ms$



(c) for $v_1 = v_2 = 40\%, t_1 = 150ms; t_2 = 50ms$

Fig.7: The contactor behavior under 90^o POW

The results obtained in Figs. 5 to 7 are plotted such as in Table 1. This Table presents behavior of the contactor drop out in the first sag and the second sag due to repetitive voltage sag under distinct the POW of sag initiation.

Table.1: The contactor behaviour due to repetitive voltage sag

First Sag Duration	Caused by first sag			Caused by second sag		
	POW of voltage sag initiation					
	0°	45°	90°	0°	45°	90°
	Time to trip in cycle					
50ms	1.5	1.5	1.5	1	1.5	2
100ms	1.5	1.5	1.5	1	1.5	2
150ms	1.5	1.5	1.5	1	1.5	2

Through Figs 5 to 7 can be observed that time duration need by contactor to drop out under 0^o POW in the first sag (around 1.5cycles) is longer than in the second sag (around 1cycle). For 45^o POW, time duration of contactor to drop out in first and

second sags is similar to 1.5 cycles. Therefore, there is no time difference between first and second sags forcontactor to drop out, even though sag duaration is applied on first is not same. Hence, the POW is not influenced on the time duration. The contactor was applied by repetitive voltage sag with 90^o POW and it drops out in first sag and in second sag around 1.5cycles and 2cycles, respectively. It means time required by contactor to drop out in first sag is faster than in second sag. This is contradictory practiced by the contactor when it was applied by repetitive sag with 0^o POW.

5. Conclusion

Distinct sag duration of first sag has not significantly effect on the contactor time to drop out in second sag, but in fact it was affected by the POW. Time duration required by the contactor is shorter than in the second sag compared with first sag when it was applied by repetitive voltage sag with 0^o POW. Otherwise the contactor to drop out in the second sag is longer than first sag when it was applied by repetitive voltage with 90^o POW of sag initiation. There is no effect on time duration the contactor to open while applied repetitive voltage sag under 45^o.

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