ELIMINATING NULL WIRE, IMPROVING POWER QUALITY AND LOSS REDUCTION BY DESIGNING THREE PHASE LOW VOLTAGE DISTRIBUTION NETWORK PASSIVE DEVICE

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ABSTRACT

Each year energy losses waste significant electrical energy and will have a massive disadvantages for the utilities. Generally power system losses is more due to losses in distribution network and this is due to, reactive power flow, unbalance phase current , and harmonic currents.in this paper designing a passive device is suggested and simulated. This device is installed between consumer and distribution network in order to balance load current, eliminate null wire, improve power quality and reduce losses.

INTRODUCTION

Unbalanced phase currents, harmonic currents and existence of Reactive power in power systems not only cause energy losses but also power quality distortion. By designing a device with the ability of balancing phase current and compensate reactive power at load side and also eliminating harmonics can lead to power quality improvement and loss reduction, in addition by balancing the phase current the null wire will be eliminated and therefore the energy theft will be reduced.

In this paper we first present the results of electrical parameters measured after installing a power analyzer in central department of south Kerman electrical distribution company (SKED co.) in a two month period and coding load model in MATLAB using Discrete action reinforcement learning automata (DARLA) algorithm and then for suggesting the passive parameters of the device the results are illustrated by using continuous action reinforcement learning automata (CARLA). At the end the impact of installing the device simulated in MATLAB on the improvement of power quality is presented.

LITTERETURE:

The impact of unbalanced phase current, harmonic currents and reactive power on power losses is as follow:

Reactive power losses

According to Equation below we can show that reactive power can cause significant loss in a system:

$$P_{LOSS} = 3R(I)^2 = 3R\left[\frac{\sqrt{P^2+Q^2}}{\sqrt{3}V}\right]^2 = \frac{R(P^2+Q^2)}{V^2} \qquad (1)$$

If equation (1) be overwrite by power factor supplied by feeder we will have:

$$P_{LOSS} = \frac{RP^2}{V^2(\cos\varphi)^2}$$

As an example if we assume that an active load in a fixed feeder stays unchanged and the power factor reduce from 1 to .9 then the ration of new loss compared by old loss is as follow:

$$\frac{P_{\text{Loss New}}}{P_{\text{Loss old}}} = \left[\frac{\cos\varphi_{\text{old}}}{\cos\varphi_{\text{New}}}\right]^2 = \left[\frac{1}{0.9}\right]^2 = 1.23$$

We can conclude that a small reduction in power factor which seems suitable will increase loss to 23%. .

Unbalance current phase loss

An unbalance in three phase system not only increases losses in the system but also it will cause losses in null wire due to current flow. If we express balanced phase current by I and each phase current by I_a, I_b, I_c, we can show that:

$$I = \frac{I_a + I_b + I_c}{3} \qquad (3)$$

We can show unbalancing in each phase as:

$$d_i = \frac{I_i - I}{I} \qquad (4)$$

Where $-1<d_i<2$.

Generally we intend the unbalancing to the maximum unbalance exists in the system.

$$d = \max_{i=a,b,c}\{|d_i|\} \qquad (5)$$

Due to unbalanced phase current, null wire will experience current flow. This is expressed as:

$$I_n = \overrightarrow{I_a} + \overrightarrow{I_b} + \overrightarrow{I_c} \qquad (6)$$

If

$$|I_a| = (1+d_a)|I| \quad , \quad |I_b| = (1+d_b)|I| \quad , \quad |c| = (1+d_c)|I| \qquad (7)$$

Assume that only the magnitude of the current is unbalanced and not the angle, then we will have:

$$I_n = (1+d_a)|I| < 0 + (1+d_b)|I| < 120 + (1+d_c)|I| < 240$$

$$I_n = I\sqrt{(d_a^2 + d_b^2 + d_c^2) - (d_a d_b + d_a d_c + d_b d_c)}(7)$$

It can be concluded that only when the three phase system is balanced the null current is zero.

The loss for a three phase feeder with R resistance in each phase (equal resistance for null wire and the phase) is expressed as:

$$P_{Loos[n]} = R\left(I_a^2 + I_b^2 + I_c^2\right) + R\left(I_n^2\right)$$
$$\rightarrow P_{Loos[n]} = RI^2\left(d_a^2 + d_b^2 + d_c^2\right) + RI^2\left[\left(d_a^2 + d_b^2 + d_c^2\right) - \left(d_a d_b + d_a d_c + d_b d_c\right)\right]$$
$$\rightarrow P_{Loos[n]} = RI^2\left[2\left(d_a^2 + d_b^2 + d_c^2\right) - \left(d_a d_b + d_a d_c + d_b d_c\right)\right] \qquad (8)$$

If the feeder experience balanced situation the loss is expressed as:

$$P_{Loos[n]} = 3RI^2$$

Therefore the ratio of unbalanced situation with balanced situation is as follow:

$$\frac{P_{Loos[n]}}{P_{Loos[S]}} = \frac{2\left(d_a^2 + d_b^2 + d_c^2\right) - \left(d_a d_b + d_a d_c + d_b d_c\right)}{3} + 1 \qquad (9)$$

The loss for a sample feeder with unbalanced situation is shown in equation below:

$$d_a = 0.5 \quad , \quad d_b = 0 \quad , \quad d_c = -0.5$$
$$\frac{P_{Loos[n]}}{P_{Loos[S]}} = \frac{2\left(0.5^2+0+0.5^2\right) - \left(0-0.5^2+0\right)}{3} + 1 = 1.42$$

we can see a 50% unbalancing in two phase of a system can cause 42% increment in feeder loss which has to be taken into consideration.

Harmonic losses

As for the harmonic voltage frequency is more than skin effect frequency which occurs in the feeder's conductors, transformers and resistances will cause losses in the system. In addition high voltage frequency components can cause fouco and hysteresis losses.

Also three phase wye connection transformer harmonics are aggregated and flow through null wire which will cause losses and/or in a delta connection the transformer begins to rotate and it will cause losses in the resistance of its wiring. We have to notify that the measured parameters also may not be accurate due to harmonics.

SUGGESTED DEVICE STRUCTURE

In this section we will suggest a three phase, three wire device for consumers with 400 volt as its input and 230 volt as its output.

The benefits of this device fall into following categories:

- Because it is installed between 230 volt single phase consumers and 400 volt three phase distribution network the adverse effects of consumers on grid is reduced.
- The power factor will be improved and thus the losses due to reactive power will be reduced
- Due to balancing the input current ,losses caused by load unbalancing is reduced
- According to the increment of tall building in large cities, a device will be installed between single phase metering and three phase network by three wires. This means the null wire is eliminated.
- With eliminating the null wire energy theft is reduced
- It will cancel 3rd ,5th and 7th harmonics and improve power quality

Figure 1 shows the topology of the suggested device in a distribution network. In this structure the device will be installed in the entrance of the building and by balancing the load and eliminating the null wire, power factor will be improved and the harmonics will be canceled. The connections are designed in a zigzag form in order to have load balancing.

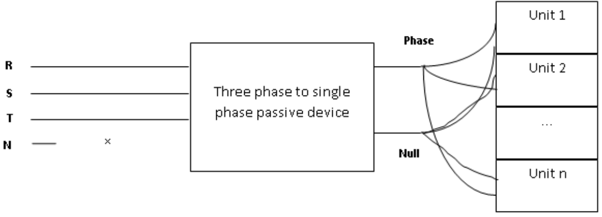

Figure 1 Passive device topology

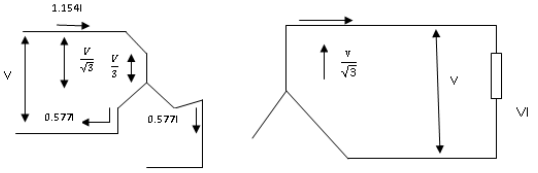

Figure 2 balancing by zigzag wiring

We have used a delta tertiary wiring in order to supply single phase load. The advantage of this wiring Y-Y transformer is:

- If the primary and secondary wiring is not delta then by using tertiary wiring a path for passing third harmonic current becomes possible.
- It would be possible to supply the load between line and null.

A 1/2 current in phase B primary wiring will cause 1/3 current in phase B tertiary wiring and therefore we can reach mmf balancing

Primary mmf + tertiary mmf= secondary mmf

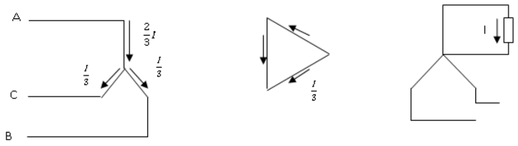

Figure 3 tertiary wiring for mmf balancing

Due to YYD connection and delta connection third harmonic will be cancelled and because of 30 degree phase shifting in wye-delta transformer, fifth and seventh harmonics in i_1 and i_2 has 180 phase shift, therefore this harmonics will also be cancelled in line current(i_1+i_2) as shown in figure 4.

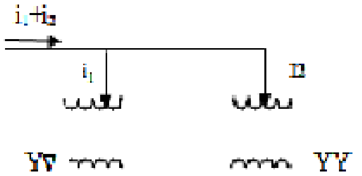

Figure 4 harmonic cancelation using YYD connection

LOAD MODEL

For modeling load parameters two methods are usually used, static load model and dynamic load model, as for static load model the active and reactive power is expressed at any instant of time as function of the bus voltage magnitude and frequency at the same instant, and for dynamic load model the active and reactive power is expressed at any instant of time as function of the bus voltage magnitude and frequency at past instant of time [2]. But as our suggested device requires a model with a harmonic behavior in each phase, we assumed the model as fixed impedance combination, linear resistance and also three nonlinear sources 3rd 5th and 7th harmonic as it has been indicated in figure 5.

In our study we measured load electrical parameters of the central department of SKED co for a two month period from 1st of July to 30th of August 2012 by installing power quality meter device. For determining the required modeling we collected the most unstable current data (with 82A null current) and it has been indicated in table 1. Then by using DARLA algorithm [1] coded in MATLAB the model was checked in order to reach the same results as table 1. After simulating the model for a three phase system, this model was simulated for each phase according to table 2. Finally we modeled the load in MATLAB as shown in figure 6.

Table 1 measured load parameters

Parameters phase	V(v)	V_1(v)	V_3(%)	V_5(%)	V_7(%)	THD_V (%)
R	229	229	1	1.8	0.7	2.3
S	219.8	219.6	2.2	2.9	0.8	3.8
T	230	229.9	0.9	1.4	0.5	1.9
parameters phase	I(A)	I_1(A)	I_3(%)	I_5(%)	I_7(%)	THD_i (%)
R	77.3	76.5	10.6	5.1	4.1	13.3
S	139.1	136.1	18.3	8.7	5.5	20.7
T	68	67.2	8.1	4.7	3.2	10.3

Table 2 modeled load parameters

Parameters Phase	R (Ω)	L (mH)	I_3 (A)	I_5 (A)	I_7 (A)	THD_i (%)	THD_v (%)	V (V)	I (A)	cos φ
R	47	4.07	12.22	4.15	5.05	13.03	3	229.9	77.01	0.82
S	58.5	2.2	33.03	16.6	14.47	20.35	3.04	227.6	139	0.91
T	33.4	٨.۴	7.12	2.62	5.37	10.12	2.99	230.1	67.61	0.86

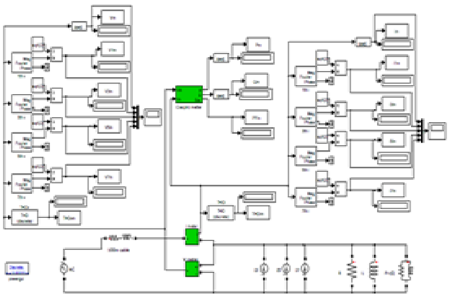

Figure 5 simulated circuit for load model

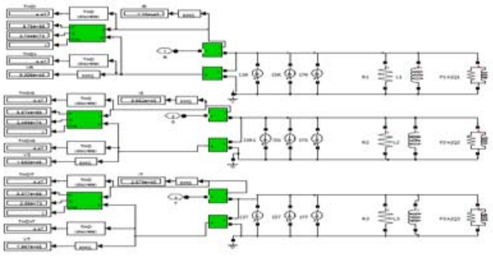

Figure 6 simulated three-phase load model

SIMULATING AND DETERMINING PASSIVE DEVICE PARAMETERS ACCORDING TO POWER QUALITY

According to section 2, the device was modeled in MATLAB by three single phase transformers with ratio number one, in both sides, as shown in figure 7. Also as it is shown in figure 7, the passive filter is installed parallel in order to cancel harmonics and improve power quality.

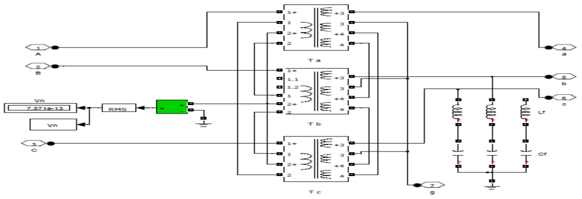

Figure 7 simulated device

For determining an optimum parameter for the suggested device CARLA algorithm has been used.

$$Cos\,t\ Func\ = \propto_1 unbalancing + \propto_2 THD + \propto_3 P.F$$

For the topology shown in figure 8, CARLA algorithm is used to optimize cost function and also to calculate the values of the indicator and capacitor and the results are indicated in table 3.

Table 3 passive device parameters

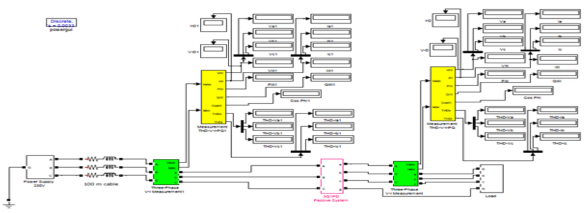

Figure 8 simulated device for improving power quality

parameter / description	Lb(mH)	Lc(mH)	Cb(mF)	Cc(mF)
Parameters value	2.2875	2.175	0.4962	0.6462

parameters

CONCLUSION

The impact of installing the device on load balancing and power quality improvement is simulated.

The results of the device impact before and after installing on power quality is shown in table 4.

Table 4 comparing power quality parameters with and without passive device

parameters / description	I_a (A)	I_b (A)	I_c (A)	Unbalance current(%)	THD_v average	THD_i average	$\cos\varphi$
Without passive device	77.01	139	67.61	28.5	3	14.5	0.86
With passive device	84.12	89.04	86.76	2.9	2.99	6.92	0.98

According to the results presented in the paper , after installing the device, the unbalance current and THDi is reduced to its standard limit , and also the voltage in the center of zigzag wiring of the device is 1.169e-12 (approximately zero) and this means the magnitude of 3rd harmonics is low.

As for the losses in a three phase feeder with R resistance in each phase is equal to

$$P_{Loss} = R\left(I_a^2 + I_b^2 + I_c^2\right) + R\left(I_n^2\right)$$

According to the resistance between cable and transformer with R=0.028 ohm, and the ampers mentioned in table 8, the loss is equal to:

A. The magnitude of losses without passive device(with 82.1 null current)

$$P_{Loss} = 0.028 \times [(77.01)^2 + (139)^2 + (67.61)^2] + 0.028 \times (82.1)^2 = 1024(V)$$

B. The magnitude of losses with the passive device

$$P_{Loss} = 0.028 \times [(84.12)^2 + (89.4)^2 + (86.76)^2] = 631(V)$$

Therefore if the reactive power can be compensate at load side, we can reduce losses due to reactive power flow. The ratio between new losses and initial losses is as follow:

$$\frac{P_{Loss\ New}}{P_{Loss\ old}} = \left[\frac{\cos\varphi_{old}}{\cos\varphi_{New}}\right]^2$$

As for using passive device the impact of power factor improvement on loss reduction is indicated as:

$$\frac{P_{Loss\ New}}{P_{Loss\ old}} = \left[\frac{0.8634}{0.9812}\right]^2 = 0.77$$

And loss is equal to: $631 \times 0.77 = 486(W)$

We can conclude that the new loss is nearly 48% of the initial loss, in other words loss reduction is approximately 52%.

Briefly we can indicate the advantage of using the suggested passive device as follow:

- Balancing load current on load side and therefore reduce loss due to load unbalancing
- By eliminating null wire the possibility of energy theft is reduced
- By cancelling 3rd 5th and 7th harmonics it will avoid power quality distortion flow to other consumers and primary side.
- it will be possible to increase distribution network capacity from 400 volt to 420 volt by using a 20KV/400V transformer and therefore reduce current and network losses.

REFERENCES

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2- IEEE Task Force on Load Representation for Dynamic Performance , "Load representation for dynamic performance analysis", IEEE Transactions on Power Systems, Vol. 8, No. 2, May 1993