14th International Conference on DEVELOPMENT AND APPLICATION SYSTEMS, Suceava, Romania, May 24-26, 2018

Study of a System for Reducing Electricity Losses

Mihai CENUȘĂ, Mihaela POIENAR, Dan Laurențiu MILICI
"Ștefan cel Mare" University of Suceava, Romania
Suceava, România
mihaela_poienar@yahoo.com, dam@eed.usv.ro, ovidiu.tanta@yahoo.com

Abstract- **Improving energy efficiency is one of the priority elements of the energy strategy both in our country and in the world. Increasing energy efficiency has a major contribution to delivering food security, sustainability and competitiveness. In addition, increasing efficiency in electrical networks is done by developing and applying solutions that reduce electrical power losses. Considering that the share of household electricity consumption is growing worldwide, this paper presents a solution for reducing the energy losses caused by the current unbalance in a low-voltage electrical network in which most receivers are single-phased.**

Keywords—unbalanced regime; power loss; smart relay

I. INTRODUCTION

In the exploitation and planning of the power distribution systems development, an important role is attributed to the study of the non-symmetries occurring at a point of the network or simultaneously at several points. Depending on their appearance, non-symmetries can be divided into two categories, namely [1], [2]:

- longitudinal non-symmetries, in case of different impedances on the three phases of the network or interruption of a phase.
- transversal non-symmetry, including non-symmetrical short circuits and unbalanced charges.

The latter, which are not accidental in fact, are treated as non-symmetries, seeking, in particular, to adopt appropriate symmetry measures.

The network is defined as balanced if the impedances on the three phases are identical, meaning they have the same module and same argument. Unequal loads can determine the permanent non-symmetric regime on the three phases of the power supply network, single-phase receivers, two-phase receivers, unbalanced three-phase receivers and different impedances on the three-phase power lines. In the case of consumers, the influence of non-symmetrical regimes has specific aspects depending on some receiver characteristics. Thus, the presence of non-symmetrical tensions at the rotary machine terminals leads to a considerable increase in active power losses. Important negative effects also occur in case of unbalanced supply of condenser batteries [3], [4].

For the existing power distributor, the unbalanced regime determines the increase of the technological production consumption, by additional loss of electric power on the electric line and negative influences in the protection system functioning. Besides the negative influences highlighted, the current unbalance also causes a problem of interference with the telecommunication systems. There may also be tensions in the water or gas networks near the electrical network [1], [4],[5].

It is virtually impossible to achieve a perfectly symmetric supply system, but by mitigation measures, the effects of voltage unbalance on user installations can be maintained within the limits allowed by normative regulations. The general solution for limiting the unbalance occurring in real cases is usually to reconfigure the power supply schemes so as to ensure a virtually equal loading of the three phases.

The sizing of these installations must be performed in cooperation with the network operator so that other aspects of the quality and efficiency of the electricity transfer to users are also taken into account. In medium and high frequency voltage networks, symmetry schemes can be made in three ways: with single-phase transformers, with compensation (Steinmetz scheme) and with auxiliary circuits.

In low voltage grids, the most effective method of limiting non-symmetry is to connect single-phase loads to the three phases to ensure symmetric loading. It is the network operator's obligation to take the necessary measures for equally loading the three phases [3], [6], [7].

The current technical solution for limiting energy losses (due to unbalance introduced by single-phase consumers in low-voltage electrical network is given by the reconfiguration of their power supply scheme.

This is realised by switching consumers from one phase to another periodically, depending on the recorded measurements. The major drawback of the solution is that the symmetrisation of electrical loads is achieved only for a short period, given that consumption is variable over time [3], [7].

A technical solution for the connection of single-phase loads in a low-voltage network is presented in this paper to ensure a symmetrical operation. By applying this solution, it is intended, in particular, to reduce the electrical energy losses caused by the non-symmetry of the line current system.

The main advantage of the solution proposed by the author compared to the ones applied by the electricity distributors is given by real-time allocation control of the single-phase consumers on the three phases.

II. DESCRIPTION

A proposed solution for reducing power losses due to unbalanced consumption on the three phases of an electrical distribution network introduced by single-phase consumers consists in switching the single-phase electric load to any phase at any one time. An electrical distribution network operating in unbalanced mode will lead to voltage unbalance on the three phases ant the most charged phase will have the lowest voltage. Taking into account this dependent voltage - charge (current) relation, the device for reducing the unbalanced power loss (DRPRD) will switch, under certain conditions, to a consumer that, at a certain moment on the most charged phase, is having the smallest voltage of the three phases, on the least loaded phase.

The device is based on a smart relay equipped with at least three 240-volt analogue inputs (network voltage) through which the voltages of the three phases and three digital outputs will be purchased for the choice of the phase supplied to the single-phase consumer. Input data processing (voltage value) and setting switching conditions will be done by a smart relay activating one of the three digital outputs. Output of the ON/OFF relay will feed the coil of one of the three contactors (one for each phase).

All component parts of the device will be protected against the effect of overloads and short circuit with automatic circuit breakers.

To eliminate the voltage gaps due to switching, the device will incorporate an uninterruptible power supply (UPS). This will ensure an autonomy of the consumer's maximum absorbed load over a period of several seconds. Since the speed of closing/opening contacts of contactors may differ from one another, switching the consumer from one phase to another will be achieved with a minimum of 1-second delay. To avoid the simultaneous connection of two contactors (e.g. due to a relay erroneous functioning), an electronic interlock between the three contactors is made so that at one point, only the contacts of a single contactor can be closed.

Passing the consumer from one stage to another is done only if at least the following conditions are met:

- the voltage difference between the two phases is greater than 2 %;
- since the last switching of the consumer, more time has passed than the charging time of the UPS battery.

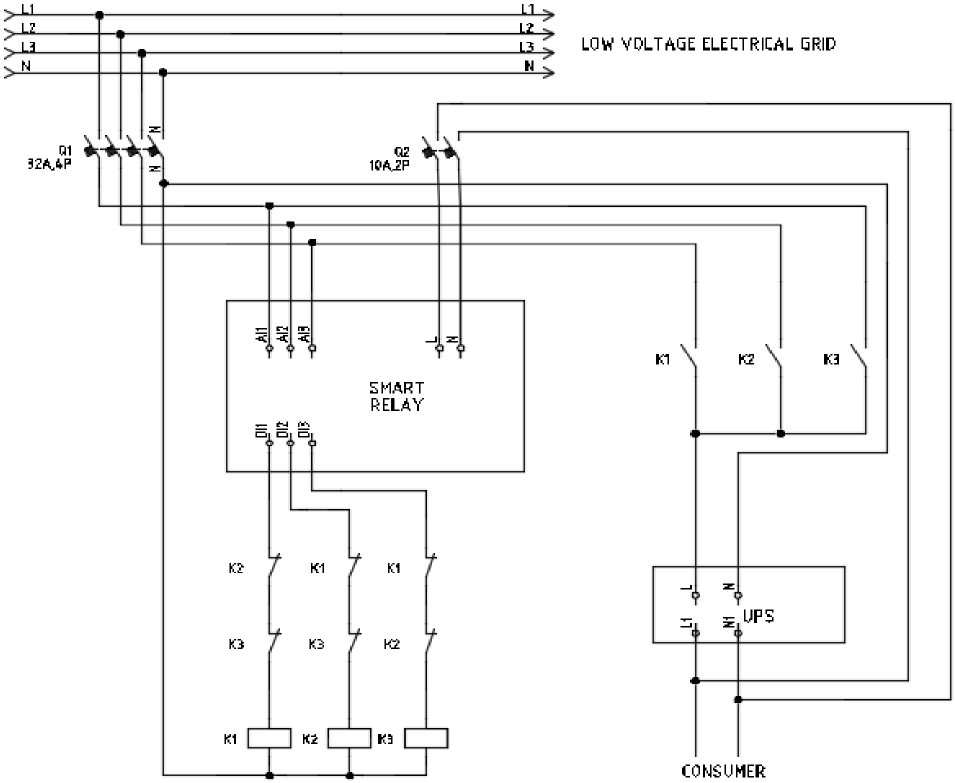


Fig. 1. Electrical DRPRD diagram.

The electrical scheme of the device is shown in Figure 1, where Q1 and Q2 are the automatic safety fuses, AI1..3 and DI1..3 are the analogue inputs, respectively the digital outputs of the relay and K1..3 are the electrical contactors.

Figure 2 presents the electrical connection diagram to the electrical distribution network of a single-phase consumer by means of the device for reducing losses that are due to unbalanced operation.

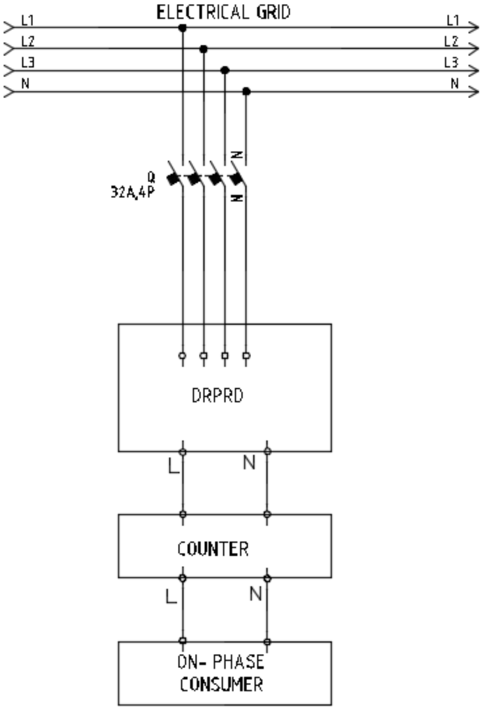


Fig. 2. Electrical diagram for electrical grid connection

For laboratory testing, a device based on a smart Schneider constructive relay was built, as shown in Figure 3, being equipped with 4 analogue inputs and 4 digital inputs. For labour safety reasons, 24-volt working voltage was chosen for the test device. The relay is powered by a 24 V voltage supply. The maximum admitted voltage on the analogue inputs is 30 V and 230 V on the digital outputs.

Fig. 3. Smart relay

As a power supply, a three-phase transformer having a 400/24 V voltage that can be assimilated to the voltage transformers in the electrical distribution networks was used. Figure 4 shows the assembly scheme used in the laboratory to test the device. In order to simulate the variation of the electric energy consumption, a rheostat marked on the diagram with R1, R2 and R3 was mounted on each of the three secondary phases of the transformer and RL represents the electrical resistance of the line. The electric consumer connected to the electric distribution network through the presented device is represented by an electric resistance of an Rc constant value.

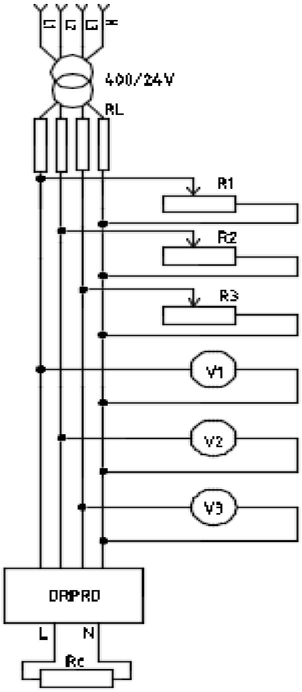


Fig. 4. Assembly scheme

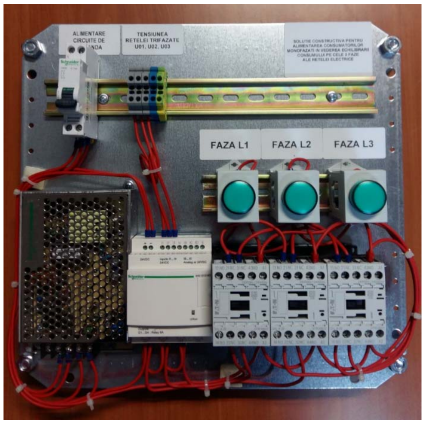
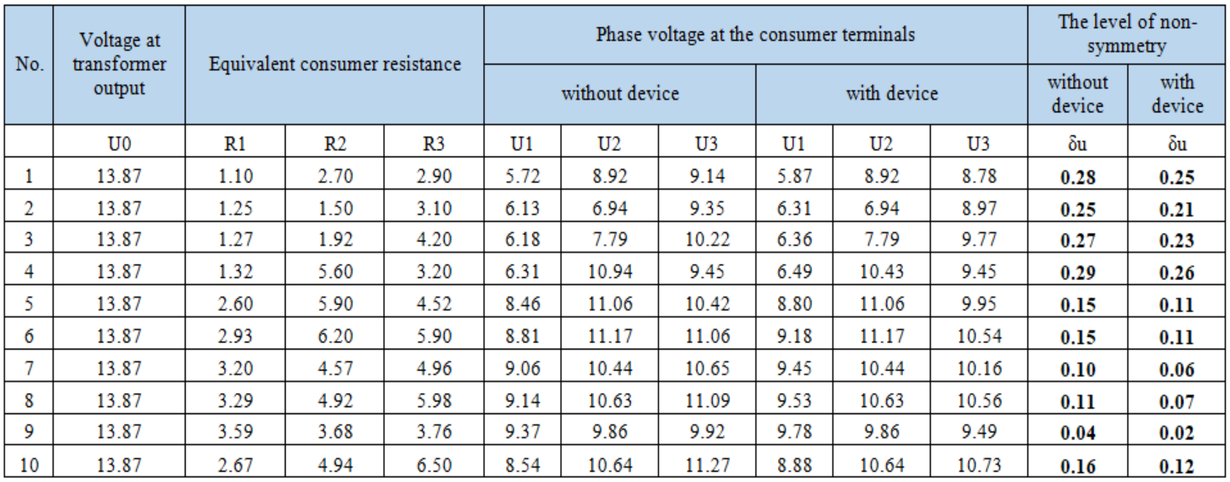


Fig. 5. Tested device

In figure 5 is presented the experimental solution for the tests made in the laboratory.



No.	Voltage at transformer output	Equivalent consumer resistance			Phase voltage at the consumer terminals						The level of non-symmetry	
					without device			with device			without device	with device
	U0	R1	R2	R3	U1	U2	U3	U1	U2	U3	δu	δu
1	13.87	1.10	2.70	2.90	5.72	8.92	9.14	5.87	8.92	8.78	**0.28**	**0.25**
2	13.87	1.25	1.50	3.10	6.13	6.94	9.35	6.31	6.94	8.97	**0.25**	**0.21**
3	13.87	1.27	1.92	4.20	6.18	7.79	10.22	6.36	7.79	9.77	**0.27**	**0.23**
4	13.87	1.32	5.60	3.20	6.31	10.94	9.45	6.49	10.43	9.45	**0.29**	**0.26**
5	13.87	2.60	5.90	4.52	8.46	11.06	10.42	8.80	11.06	9.95	**0.15**	**0.11**
6	13.87	2.93	6.20	5.90	8.81	11.17	11.06	9.18	11.17	10.54	**0.15**	**0.11**
7	13.87	3.20	4.57	4.96	9.06	10.44	10.65	9.45	10.44	10.16	**0.10**	**0.06**
8	13.87	3.29	4.92	5.98	9.14	10.63	11.09	9.53	10.63	10.56	**0.11**	**0.07**
9	13.87	3.59	3.68	3.76	9.37	9.86	9.92	9.78	9.86	9.49	**0.04**	**0.02**
10	13.87	2.67	4.94	6.50	8.54	10.64	11.27	8.88	10.64	10.73	**0.16**	**0.12**

Fig. 6. Tested device

Figure 6 shows a set of values obtained in the laboratory when a single-phase consumer is supplied through the device. To simulate line resistance, were used four resistors having a value of 1.5 ohm and a 24 ohm resistance for the consumer. Three variants of power consumption were simulated on the three phases, upstream of the consumer. From the data analysis it can be seen that the level of network mismatch decreases when the solution presented is used even by a single consumer. This directly results in the reduction of electric power losses.

III. CONCLUSIONS

The power supply of the single-phase consumers through the device presented will lead to a better distribution of the consumption on the three phases, obtaining for the electrical network a working regime approaching the equilibrium. This will reduce the loss of electricity in low-voltage electrical networks. Keeping in mind that smaller smart relays/programmable automatic relays appear on the market, the device can be integrated directly into the electricity meter.

By implementing the presented solution, the quality of the distribution service will be improved by increasing the degree of safety in the supply of electricity to the single-phase consumers. For example, if at a given time appears a „phase failure” electrical fault in the electric grid, the consumers on this phase will be transferred to the other two functional phases. In addition, short-term voltage gaps will no longer be felt by consumers as they are taken over by the UPS.

ACKNOWLEDGMENT

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI – UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0404 / 31PCCDI/2018, within PNCDI III.

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