A MODEL OF AN AUTOMATIC PHASE SWITCH

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ABSTRACT

The electric distribution network in Nigeria is beset with anomalies in the form of frequent fluctuations, sub-standard voltage and outages that damage both distribution as well as consumer equipment. Residential Consumers have evolved responses to most of these problems by proactively changing the phase to which they are connected. The method used is to bring all three phases to an accessible point and manually select the perceived best phase. This paper presents a model that can help in doing this and effecting load balancing in the system. Issues of transients and overall system stability is considered and it is concluded that if supply authority should allow for such a system, the consumer and the distributing authority will be better for it.

INTRODUCTION

Power distribution in Nigeria is done predominantly at 415V phase–phase on 3–phase, 4–wire system. Usually, transformers rated between 50 and 500kVA are used at substations to supply groups of residential and commercial consumers in a radial manner. The high demand for electricity has resulted in overloading at most substations which leads to frequent outage and other anomalies. For the 3–phase system to function with minimum power loss, the leads on the phase must be balanced or as close to balanced as possible. This amongst other requires that the load be balanced. Load balancing is the process whereby loads/consumers are shared amongst the phases in such a manner that the total load at any time on each phase will be approximately equal [1]. [2 and 3] presented phase switching algorithms that can be used for optimal phase balancing switching sets of loads. There are three possible methods of achieving this as highlighted below.

LOAD ESTIMATION BEFORE CONNECTION

In the first method, estimates of the load are used as the basis for allocating the phase to which a consumer is connected in the first instance when being first energized. Unfortunately this estimate often depend on factors that may change such as diversity factor which means the deviation from balance could be quite marked. In a system which is running well within its capacity, this technique can be applied and the deviation from balance may be no more than 20% of the rated current. Unfortunately in Nigeria, except at the inception of a new feeder or in isolated and well-managed loads, the distribution lines are overloaded. This situation coupled with widely changing loading patterns by the consumers can in many instances lead to differences in phase current in the excess of 100%. Automatically losses are very high, and balancing will be required.

In the Nigerian system, maintenance procedures do not include regular and periodic assessment and balancing of the phases. As elsewhere, the largest number of consumers is residential consumers who by regulation must be connected with a single phase meter, usually with maximum amperage of 100A.

Due to the very rapid growth of electric power distribution occasioned by consumer demand, new connections are often done without being recorded. It is further exacerbated by the fact that the lines are substantially overloaded before hand. The resource needed to carry out an authority-supervised balancing operation is very high and may not even be achievable given the dynamic nature of many loads. As a result, no positive actions have been taken in recent times.

CONSUMER AD-HOC APPROACH

The second "method" is the response of helpless consumers to the extreme conditions which damage their equipment and curtail their access to quality electric power. In Nigeria this problem is further exacerbated by the frequent occurrence of single and two phase faults where consumers observe their neighbours having power whilst they languish in darkness. They have since evolved a technique whereby single phase consumers demand and connect all three phases to a board in their houses through fuse points which are only used one at a time as illustrated in figure 1

The arrangement in principle is fraught with great difficulties and dangers since one may believe that two or more of the phases may be connected together at the

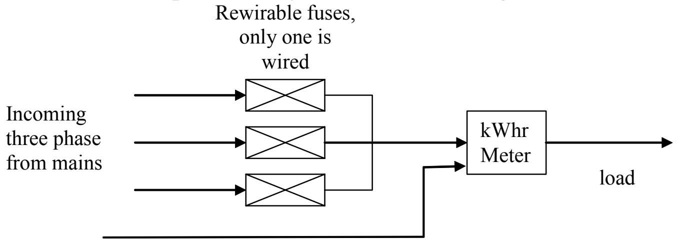


Figure 1: Consumer ad-hoc load balancing method

injection point of the consumer. Indeed, the power authority frowns seriously at this practice but they are relatively powerless to stop it since the enforcement of any sanction would lead to potential social upheaval.

In a recent study, it was observed that this method has become almost institutionalized in Nigeria. An assessment of accidents occurring as a result of this modification indicates that because the consumers have only one fuse for the three fuse points, an automatic virtual mechanical interlock exists preventing the simultaneous closure of two or more of the phases to the consumer injection point. The rationale used by the consumers to select their operating phase may be described as an "eyeball" method. When a consumer observes deterioration of the voltage through the level of illumination evident from the light and the fan speed, he proceeds to transfer his mobile fuse from one phase to another until he finds the best voltage through the observation of his illuminations. This procedure when considered heuristically will mean that the consumer has actually taken the first step to reducing the load on his initial phase and increasing that on the terminal phase, which is an incremental step to balancing the load.

Ideally, a set of consumers carrying out this process may end up at achieving 'a balance of the loads'. This method however has many flaws because the consumer who is actually closing the feedback loop cannot be precise and consequently may cause oscillation in the loading patterns. Despite the potential for accidents, the resulting system has proven to be as efficient as nay mechanical-interlocked one. However, since the migrations usually increase the load on the 'good' phase, losses increase and terminals at feeder pillars are damaged. This could as well lead to the damage of the supply transformer and ancillary equipments.

AUTOMATIC PHASE CHANGER

It is easy to imagine an automated system which depends on imprecisely stated guidelines to select the phase with the best voltage each time and in addition includes other criteria that will prevent systemic oscillations.

The third method is a theoretical one whereby an automaton which may use a microcontroller is installed at each loading point and can be directed by some central authority through the agency of another automaton to periodically adjust the phase of each consumer. Naturally, this method has many advantages which however introduce additional but complex equipment at each installation.

Best Phase Selection Algorithm

There are six valid possible scenarios for the values of the phase voltages. These are depicted graphically in figure 1

Let

$\Phi1$ is the phase to neutral voltage on phase 1,

$\Phi2$ is the phase to neutral voltage on phase 2, and

$\Phi3$ is the phase to neutral voltage on phase 3.

Also let

A be the Boolean variable which is true when the condition $\Phi1 > \Phi2$,

B be the condition that $\Phi2 > \Phi3$,

C be the condition that $\Phi1 > \Phi3$,

X1 is the output with only phase 1 selected,

X2 is the output with only phase 2 selected

X3 is the output with only phase 3 selected

The characteristics table of the machine is shown in table 1

Table 1: Characteristic table of automatic phase selector

S/N	A	B	C	X1	X2	X3	Remark
1	1	1	1	1	0	0	Phase 1 is selected
2	1	0	1	1	0	0	Phase 1 is selected
3	0	1	0	0	1	0	Phase 2 is selected
4	0	1	1	0	1	0	Phase 2 is selected
5	0	0	0	0	0	1	Phase 3 is selected
6	1	0	0	0	0	1	Phase 3 is selected
7	1	1	0	Fault state (implementing a fail/safe mechanism)			APS disabled, primary phase selected.
8	0	0	1				

Electronic Implementation of Phase Selector

The first component of the phase changer is the voltage measurement system. All the three phase voltages are measured individually. The voltages are then presented to a set of comparators whose output provide the variable A, B and C as shown in table 1. The phase change is now implemented according to the logic indicated in the characteristic table 1. All these functions can be easily and readily implemented with a simple microcontroller equipped with at least a three–channel analog–to–digital converter.

The problem when many of such switches are connected into a system is interesting. For example, if they are all connected through identical automatic phase switches as above, a situation may arise when all may be switched to the same phase at the same time in the event of low voltage or outage on other phases. This can cause oscillation of the switches as they will switch back and forth between phases. This oscillation can damage distribution transformers easily. In order to solve this problem, a random timer is inserted so that phase changes occur randomly. This will ensure that when a system migrates from one phase to another, other systems will wait for some time before taking phase change decisions, in the case that the switching of the already switch loads will balance the system. The other effect that this have on the system is that the feeder pillar is prevented from rupturing as a result of all consumers switching to a single phase.

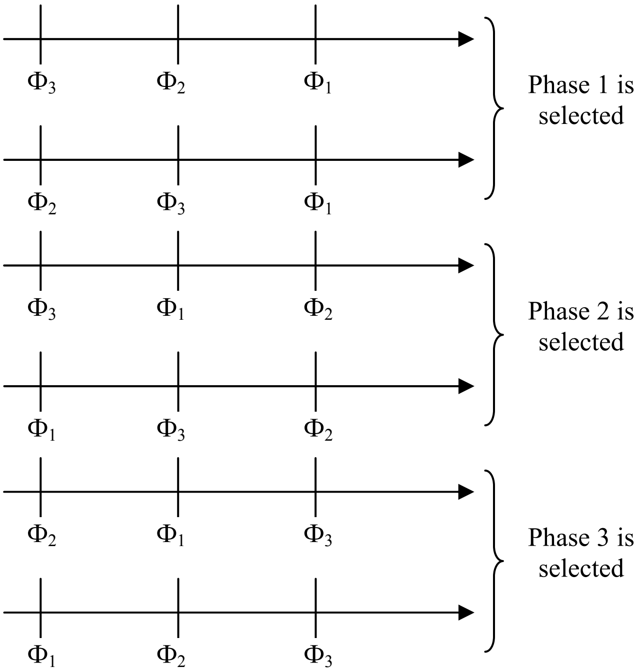
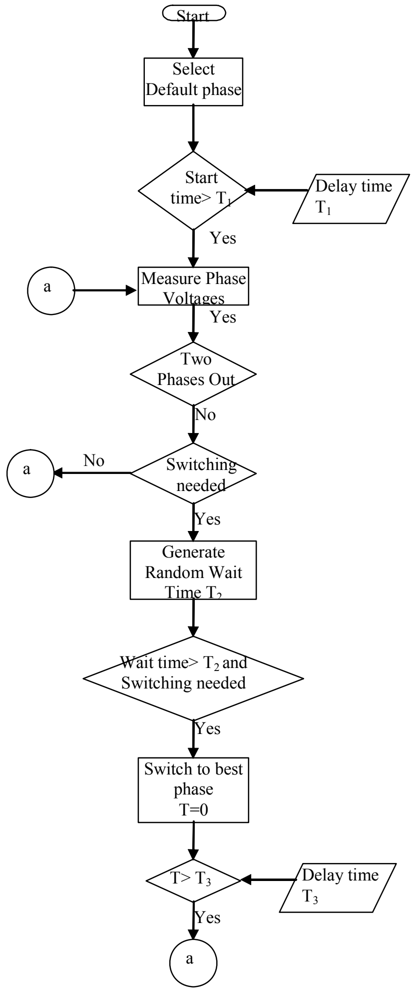


Figure 2.

Another step to prevent such possible problems is by embargoing migration when two phases are outaged. Logic is also needed to take care of default conditions occurring at start-up or restart as the case may be. The introduction of these phase solutions into the distribution system can be made more workable by placing limits on the time between migrations. When all these effects are combined with random delays, the effect of the selectors will occur at a rate that is manageable. Figure 3 shows the flowchart of the proposed system. A special paper will present the result of simulations of the effect on local systems as well as proof of convergence.

CONCLUSION

The regulations in Nigeria have been that all single phase wired residential consumers should be supplied via single phase in line with the IEE standard. Regulations should be made if they can be enforced and it is in the long–term interest of the system. This wiring standard as at present in Nigeria is neither enforceable nor in the overall interest of the electric distribution system in the country. It will be better if this standard is changed and an automatic system be allowed to control the switching of consumers between phases as against the present "eye–ball" method. This will allow for the development of this model with the consequent improvement in the phase balance in our electric distribution system.



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