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How to Deal with Intermittent Loads

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Abstract: Electrical power industry comprises of different types of loads to deal with a variety of process-related requirements. Fixed, variable, continuous, standby and intermittent etc. are various examples. Amongst all the different kinds, the intermittent loads are considered the most pollutant. Intermittent loads differ from the conventional loads in a way that these loads are only energized for a fraction of their connection time. These loads subject the electrical power system to a number of planning and operational issues. From costly distribution systems to utility penalties and compromised service lives of other connected equipment, the intermittent loads challenge the designers at every step. It is necessary to check a system's compatibility before installing intermittent loads to ensure that their unique requirements can be supported. This paper identifies and solves various planning and operational challenges pertaining to the use of intermittent loads.

Keywords: Intermittence, power quality, non-linear loads, stochastic analysis

I. INTRODUCTION

Intermittent loads like welding equipment, motor starting, electric furnaces, grinders, reciprocating pumps, medical equipment like x-ray machines, insect killers etc. draw excessive currents for very small durations. [1] The degree of intermittence of an intermittent load is reflected through duty cycle of its operation, expressed in percentage. Most intermittent loads have very low duty cycles. Welding load for example has a duty cycle in the range 1-10%. [2]

With regards to intermittent loads, effective planning is required to prevent the supply and distribution system capacities from being under-utilized. Intermittent loads deteriorate the quality of power at the point of common coupling [3]. They subject the power system to various issues like voltage flickering, poor power factors, harmonic hissing, unexplained protection failure, voltage imbalances, and voltage sags etc. [4-6]

This paper explains the various challenges concerning the use of intermittent loads and provides effective solutions to handle them.

II. CHALLENGES

This section will discuss various planning and operational stage issues concerning the intermittent loads.

A. High-connected-low-instantaneous load

Intermittent loads reflect a low diversity factor on the system they're connected to. Intermittence combined with the randomness (due to manual initiation) results in very low instantaneous load for a very high connected load. If the system is designed for the connected load, the system's capacity would remain underutilized for most duration. On the other hand, if the system is to be designed for instantaneous load, the instantaneous loading first has to be determined. For intermittent loads, determination of average instantaneous loading is a challenge.

B. Voltage Flicker

Voltage flicker is a noticeable variation in the intensity of light due to rapid fluctuations in the voltage of the power supply. Voltage fluctuation is the internal fault condition which corresponds to the fast switching of loads while voltage flickering is the visual representation of voltage fluctuation. Voltage flicker occurs when the loads draw subharmonics and inter-harmonic currents. This causes annoying interference and fluctuation in the intensity of light [7].When the rate of variation is 8 cycles per second, voltage fluctuations as low as 0.3 V are detectable in ten percent of the observations .Since, the intermittent loads draw high magnitudes of currents for short durations, they cause the voltage to drop abruptly; hence, causing fluctuations [8].

C. Voltage imbalance

Generally, in the three phase system the set of voltages and currents is always equal in magnitude while their phase angles are 120 degrees apart. The difference in these parameters leads towards voltage imbalance. When single phase heavy loads are connected to the three phase power system, the excessive power draw through one of the phases makes the other two phases under-loaded. This unbalancing drives excessive neutral currents leading to copper losses and malfunctioning of various equipment. With intermittent loads, no matter how equitable the distribution be amongst the phases, the instantaneous load will always be unbalanced unless synchronized. The allowable voltage imbalance is 2% of nominal voltage rating which is almost unachievable with intermittent loads [9].

D. Total harmonic distortion

Intermittent loads draw current in the form of irregular pulses injecting the system with harmonics. Total harmonic distortion is used to quantify the effect of harmonics in the system. The continuous or linear loads have sinusoidal waveforms having single frequency component while intermittent loads are non-sinusoidal in nature. These frequency components due to the deviation of sine waves cause the harmonic distortion in the system [10]. Intermittent loads require power electronics based controls to regulate the duty cycle. Power electronic devices cause variations in frequencies resulting in the deviation of sinusoidal wave [11]. The allowable total harmonic distortion limit is 5% with single harmonic not more than 3% and systems having THD greater than this limit can have serious consequences including wire overheating, malfunction and destruction of a device/system [12].

E. Voltage sagging

Voltage sagging is the transient drop in magnitude of voltage (i.e. 0.5-30 cycles) usually caused by a distant fault in power system. These faults may live for a very short period of time in the system [13] but it can cause wide range of damages to equipment. Due to profuse utilization of electronic devices in circuits, a voltage sag lasting for only small fraction of time can stimulate high production losses [14]. The problem of voltage sag arises in intermittent loads because they draw large amount of current intermittently. When the intermittent pulses overlap, the system may experience voltage sagging. Sagging can have severe consequences ranging from slowing down of computer controlled machines to failure of devices. It can also cause false relay operations in ELV devices resulting in their isolation from the main system.

F. Reactive power demand

Active and reactive power are interlinked and both are essential for the system to perform efficiently. Reactive power (VAR) plays a vital role in regulating voltage levels in the system while active power performs useful work. The use of intermittent loads like rolling mills, welding loads, insect killers has increased greatly. As intermittent loads cause varying voltage profiles, the systems reactive power demand increases, concerning the consumer with regards to high losses and utility penalties. [15]

III. MITIGATION

A. Planning stage

Effective planning can help solve various issues before they appear. Following section discusses some methods to deal with intrinsic difficulties related to the use of intermittent loads.

I. Reduced network impedance

The impedance of the mains has an important contribution to worsening the deteriorated power quality due to intermittent loads. High impedance causes voltage sags, under voltages, harmonic noises etc. The impedance of the mains is a summation of a number of impedances, in essence, source impedance, feeder impedance, transformer impedance, etc. Transformers, however, represent the highest percentage of the impedance in a facility. Conventionally transformers are specified at 6% impedance. Significant improvement in the power quality is anticipated if the transformer feeding the intermittent loads is specified at low impedance for say 4%. Although low impedance transformers are costlier than generic transformers, but the reduced line losses and cost savings due to improved power quality make their use feasible. [16]

II. Separate supply & distribution

The effect of power quality deterioration due to intermittent loads can be minimized by separating their supply and distribution networks from other loads. For example it might not be a good idea to connect lighting load to the transformer feeding the welding equipment. The flickering in which case shall create an annoying working environment. Extending this approach to circuit level, it's not prudent to loop insect killers with any other equipment, lights or sockets. [16]

III. Overloading without overheating

The fact that the intermittent loads do not need the supply to be committed for all the while they're in operation, allows optimization of their feeder ratings through thermal equivalence. A feeder rated at the connected load is wasteful and unnecessary. A smaller current that has the same thermal effect flowing continuously as the intermittent current flowing intermittently can be used to size the distribution feeder. Using energy equation, it can be proved that for a connected load of 200A at 25% duty cycle the thermal equivalent load is 200 times the square of 0.25 i.e. 100A. A 100A feeder will be able to feed a 200A load without being overheated. [17, 18]

IV. Stochastic analysis

There may be a number of similar intermittent loads in a facility, each operating at random without any synchronism. If the loads are fed through individual cables, the cables have to be rated at thermal equivalent current of an individual load. However, if the distribution is planned with busways, the randomness in addition to the intermittence can be brought into use. For a number of intermittent loads connected to a bus, the most probable number of simultaneous operations can be determined stochastically and the thermal equivalent current corresponding to the simultaneous operations can be used to size the distribution bus way. [17, 18]

B. Operation Stage

V. Active Power Filters

Active power filters principally work by feeding the system with an antidote of the major trouble maker. Active power filters eliminate harmonics and flickers from the system by interjecting active power with similar frequency but opposite phase in the system in order to cancel the harmonics present in that system [19]. Two phase intermittent loads present in welding and furnace industries are prone to severe voltage drops and total harmonic distortions which causes damages to the components. Since, active power filters are efficient but very expensive so they are widely used in large industries rather than small circuits. For three phase system containing non-linear load current are also subjected to harmonic and reactive components. When introducing the APF into the system, the source currents are distorted having no reference so fundamental current is chosen as reference current. In APF the reference current is selected depending upon the reactive power extraction from the load. [20]

VI. Facts devices

Facts (Flexible AC Transmission System) devices are power electronic devices installed in the systems to improve the capability, efficiency and reduction of losses like voltage imbalances, harmonic distortions. There are numerous devices that exist under the banner of fact devices. Depending upon the pre-requisites of power systems facts devices are classified into three categories as Series compensators, shunt compensators and UPFC (unified power flow controllers) which is the combination of series and shunt compensators [21]. Static synchronous compensator (STATCOM), static VAR compensator (SVC) are shunt devices used for the regulation of voltage and reactive power. Synchronous series compensator (SSSC) and Thyristor-controlled series compensator (TCSC) installed for active power regulation as well as improvement in transients. Since FACTS operate dynamically, matching the pace of intermittence, they can be seen as an effective solution for improving power quality of a power systems with intermittent loads. [22][23]

VII. Fly wheel ups

Flywheel ups is the most advanced technology in which flywheel is used to provide uninterruptible energy to critical loads i.e. intermittent loads during external power outages. It bridges the gap between utility power failures and consumer end caused due to voltage sag or other losses by providing the power to the loads during that time frame and ensuring uninterruptible power supply [24]. Intermittent loads can be supplied through the sources having flywheel connected in parallel. The energy is supplied by the source during on cycles and the flywheel connected restores that energy during off cycle, ensuring a smooth voltage profile at the point of coupling. [25].

IV. CONCLUSION

This paper discussed that how intermittent loads vary from normal loads and how they affect the power system with their presence.
Innovative solutions were proposed for their handling at operational and planning stage.
Further, this paper should serve as an enabler for more detailed analysis on individual intermittent loads like welding load, grinders, medical equipment etc. and development of process-tied power supply and distribution systems for these loads.

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