Dynamic Sag Correctors: The Solution for Power Quality Problems in Industrial Section

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Abstract— Voltage sags are more intolerable problems as they directly affects the productivity of the industries. There were many solutions and electronic equipments have been proposed to mitigate such voltage sags. The series parallel connected Dynamic Sag Correctors (DySC) is proposed which provides significant protection at greatly reduced cost. DySC features that its size and weight is reduced as compared to previous equipments. It is rated from 1.5 KVA one phase to 2000 KVA three phase. This also allows operation with opened upstream circuit breakers. This paper presents detailed discussion of DySC operating principles. It also provides the conditions under which this new category of product can be applied.

Key words: Power Quality, DVR, Voltage Sags, Voltage Swells, SMES

I. INTRODUCTION

Now days, Power Quality Problem is the major issue in Industrial and Commercial Section as they can affect large number of sensitive end users. Studies indicate that Voltage sags, Transients and Momentary interruptions constitute 92% of all the Power Quality problems occurring in the distribution power systems[1]. In fact, voltage sags have always been a huge threat to the industry, and even 0.25 s voltage sag is long enough to interrupt a manufacturing process resulting enormous finantial losses[2],[3]. Voltage sags are generally classified according to its deapth and duration of time. Sag can be drop between 10% and 90% of the rated RMS voltage. It has the duration time of 0.5 cycles to 1 min[4]. According to the data presented in [5],majority of the sags with long duration time obviously cannot be ignored as they are more intolerable than shallow and short duration sags to the sensitive electrical consumers.

From the several Power quality problems the most concern is the voltage sag. The standards are needed for the effects of voltage sags on sensitive electronic equipment as reference documents describing single equipment or component and systems in power system.

Both buyers and manufacturers use these standards to meet better power compability. The most common standards dealing with power quality are IEEE, IEC, CBEMA & SEMI[6].Voltage sags are momentary interruptions caused by short circuits and fault in distribution system as shown in Fig.1.[7].

There are many power electronic devices which are used to mitigate voltage sag. The voltage regulator topologies can classify into two categories: The inverter based regulator and direct ac-ac converters. Series connected devices are voltage source inverter based regulators and they mitigate the voltage sag by injecting a missing voltage in series with grid. There are many SD topologies which are having features related to the estimation of a certain SD topology are the cost, complexity and compensation ability. Dynamic voltage restorer (DVR) is a generally used SD. Different types of DVRs are discussed in [8]. The overall study shows that DVR with no storage and load side connected for long duration deep sags at a relatively low complexity and cost.

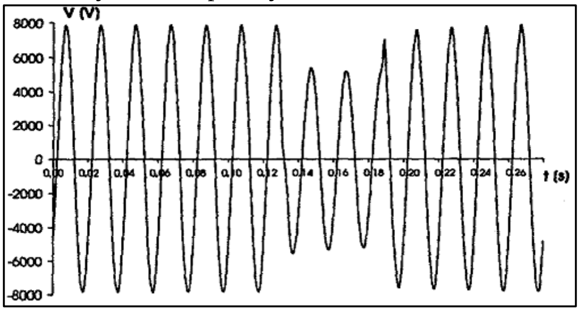

Fig. 1: Typical waveform of Voltage Sag Caused by fault clearing[7].

The DVR topology is not cost effective solution for long duration deep sags as it includes a series transformer that is heavy, bulky and costly operating line frequency. To overcome with this drawback the type of transformerless SD topology Dynamic Sag Correctors (DySC) is proposed pronounced "disk". The DySC mitigates voltage sags, transients and momentary loss of power. The transformerless implementation of the DySC constitutes the rating of 1.5 KVA single phase to 500 KVA three phase in a transformerless implementation and above 500 KVA upto 2000 KVA in series transformer is injected with the device. The unique features of the DySC that are: i) It is transformerless ii) Features single stage power conversion iii) minimizes stored energy iv) Optimally matches protection time to system characteristics.

II. POWER QUALITY PROBLEMS AND CAUSES

The survey by power quality experts indicates that among the 50% of the power quality problems are related to the grounding faults, grounding loops, ground current and other ground associated issues.

Here are the Symptoms which indicates the Power quality problems: i) piece of equipment operate at the same time of day. ii) Circuit breakers trip without being overloaded. iii) Equipment fails during a thunderstorm. iv) Automated systems stop for no apparent reason. v) Electronic systems fail or fail to operate on a frequent basis. vi) Electronic systems work in one location but not in another location [9].

The most common types and cause of the power quality problems are described in [10]. The parameters which describe the PQ problems are given below:

A. Voltage Sag

It is the decrease in voltage level between 10% to 90% of the nominal rms voltage at the power frequency, for the duration of 0.5 cycles to 1 min. The causes of voltage sag or dip are faults on transmission or distribution network, faults in customers installation, connection of heavy loads and start-up of large motors.

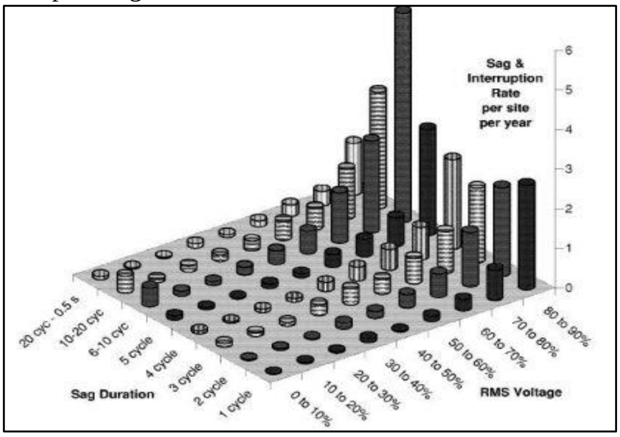

Fig. 2: Power quality problems study [12].

The influences of the voltage sags are mainly includes malfunction of IT equipment that they may affect to a process stoppage e.g., PCs, PLCs, ASDs etc., Tripping of contactors and electromechanical relays, loss of efficiency in electric rotating machines. The data given in fig.2 shows sag and interruption rate during a few cycles of duration.

B. *Voltage Swell*

Voltage swells are momentary increase of the supply, at the power frequency, outside the tolerances, with duration of more than one cycle and typically less than a second. The causes of voltage swells are start or stops of heavy loads, badly dimensioned power sources, badly regulated transformers.

The influences are data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

C. *Harmonic Distortion*

It is described as voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine waves with different magnitude and phase, having frequencies that are multiplies of power system frequencies.

III. THE VARIOUS METHODS USED TO MITIGATE THE VOLTAGE SAGS

A. *Tap Changing Transformers*

Electronic tap changing is achieved via the use of back to back thyristors (SCR) with a tap changing transformer. Has a reasonable response time (1 cycle) and is popular for medium power applications (>3kVA). However, high control resolution requires large number of SCRs (60 SCRs for +/-3% regulation with +10/-20% input range); the control for fast response becomes fairly complex. Another drawback of this scheme is its susceptibility to high transient current with motor loads upon tap changing and its poor transient voltage rejection.

B. *Saturable Reactor Regulators*

This scheme controls the output voltage by varying the impedance of a saturable reactor: it is simple and has a good line transient rejection. The drawbacks of this technique include slow response (10 cycles), high output impedance which gives high distortion with non-linear loads sensitive to load power factor, will not handle surge currents such as motor starting and will not suppress transients generated inside plant.

C. *Electronic Voltage Regulators*

They are a new class of automatic voltage regulators based on high frequency switching inverter technology. It can provide fast response (1-2 ms), sinusoidal voltages, and compact design. This category of voltage regulators potentially offers the highest performance solution. However, designing appropriate overload capability can make the overall cost unacceptably high. In order to realize a fast response and high performance electronic voltage regulator with the lower cost of the more conventional schemes, a hybrid configuration using active and passive components can be use.

D. *Static Voltage Regulator (SVR)*

This device, through the use of static tap changers, simply regulates the voltage to equipment operational levels. Unlike conventional load tap changers, which are equipped with a time-delayed mechanical tap changer, static tap changers are designed to respond instantaneously by selecting the appropriate voltage tap, on a sub-cycle basis, without the need to progress through a series of lower voltage taps.

The SVR does not require the use of energy storage[13], and it has a relatively small footprint for the amount of load it can protect. Also, it is designed to be installed outdoors so it does not intrude in the manufacturing space.

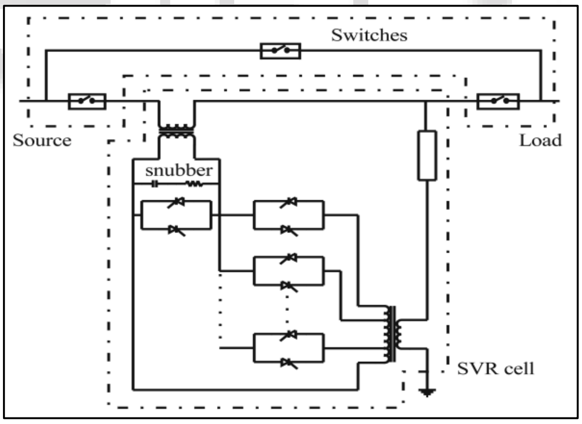

Fig. 3: Static Voltage Regulator[13].

The SVR, Fig.3, is able to correct voltage sag conditions (a 55% of the normal voltage maximum depth) in a quarter of a cycle (4 ms), to allow even the most sensitive manufacturing equipment to ride through voltage sag conditions caused by faults in the utility distribution or transmission systems.

E. *Ferroresonant Transformers (CVT)*

Ferroresonant transformers, Fig.4., also called constant-voltage transformers (CVT), can handle most voltage sag conditions (always beneath 20 kVA). In fact, they are specially attractive for constant, low-power loads. Variable loads, especially with high inrush currents, present more problems for CVT because of the tuned circuit on the output. The ferroresonant transformer core structure is designed so that the secondary operates in flux saturation and the secondary winding resonates with the capacitor in a tuned circuit. As a result of this saturated operating mode, changing the primary or line voltage may change the current but will not vary the flux or the secondary induced voltage. The output waveforms are not sinusoidal (square wave with a high harmonic content) especially with non-linear loads. A properly selected neutralizing winding cancels out most of the harmonic content of the output voltage and yields a satisfactory low-distortion sine wave[13].

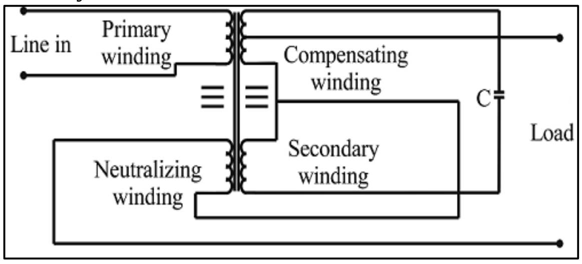

Fig. 4: Ferroresonant constant voltage transformer[13].

F. Uninterruptable Power Supply

Utilities typically use batteries to provide an uninterruptible supply of electricity to power substation switchgear and to start backup power systems. They also increase power quality and reliability for residential, commercial, and industrial customers by providing backup and ride-through during power outages. The standard battery used in energy storage applications is the lead-acid battery. A lead-acid battery reaction is reversible, allowing the battery to be reused.

There are three types of UPS that use batteries to store energy. In an on-line UPS, the load is always fed through the UPS. The incoming ac power is rectified into dc power, which charges a bank of batteries. This dc power is then inverted back into ac power to feed the load. If the incoming ac power fails, the inverter is fed from the batteries. This model provides very high isolation of the critical load from all power disturbances, but it can be quite expensive. With a standby UPS (also known as offline UPS), the normal line is used to power the equipment until a disturbance is detected and a switch transfers the load to the battery-backed inverter. A transfer time of 4 ms would ensure continuity of operation for the critical load. Finally, the hybrid UPS utilizes a voltage regulator on the output to provide regulation to the load and momentary ride-through when the transfer from normal to UPS supply is made.

G. Superconducting magnetic energy Storage

An SMES Fig.5., utilizes a superconducting magnet to store energy in the same way a UPS uses batteries to store energy. The system stores energy in a superconducting coil (Nb-Ti). The refrigeration system and helium vessel keep the conductor cold in order to maintain the coil in the superconducting state (at 4.2 ºK). Utility system power feeds the power switching and conditioning equipment that provides energy to charge the coil, thus storing energy. When a voltage sag or momentary power outage occurs, the coil discharges through switching and conditioning equipment, feeding conditioned power to the load.

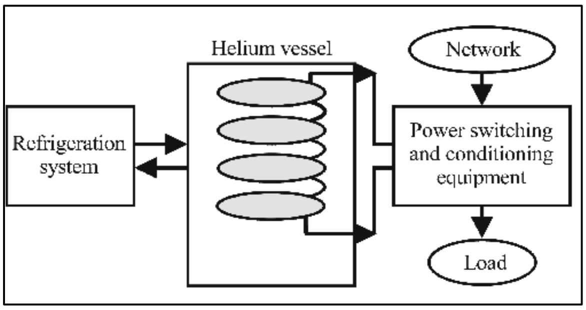

Fig. 5: SMES Schematic[13]

SMES designs in the 1 to 5 MJ range are called micro- SMES, to distinguish them from large power sizes. The main advantage of the micro-SMES is the greatly reduced physical space needed for the magnet as compared to batteries. Fewer electrical connections are involved with a micro-SMES compared to a UPS, so the reliability should be greater and the maintenance requirements less. Initial micro-SMES designs are currently being tested in several locations with favourable results.

SMES systems are large and generally used for short durations, such as utility switching events. They also reduce or eliminate the use of environmentally unfriendly, lead acid battery systems and can repeat the charge-discharge sequence thousands of times without any degradation of the magnet. Low temperature SMES cooled by liquid helium is commercially available. High temperature SMES (HTS: the coil reaches the superconducting state at -175 ºC) cooled by liquid nitrogen is still in the development stage and may become a viable commercial energy storage source in the future.

IV. DYSC

The series parallel connected Dynamic Sag Corrector provides statically significant protection at greatly reduced cost. The principles of DySC are as follows:

- Though it protects against 92% of events as expressed above, DYSC corrects voltage sags of 50% magnitude depth and up to 2 sec duration hence the cost of ownership reduced.
- The DYSC protects up to 500KVA, do not contain a series transformer and having little energy storage hence size and weight are minimized.iii) The DYSC is having static bypass switch which is normally closed until a sag event occurs so, that the operating efficiency is maximum over 99%.

The three types of DySC are given as below.The DYSC was design to provide better flexibility to the industrial customers. The DYSC is classified into three major types:

- Single phase mini DySC
- Three phase DySC
- Mega DYSCpro DySC

The detail description is given as below.

A. Single phase (mini DYSC):

The single phase DYSC (mini DYSC) is based on a patented voltage boost circuit [11]; Fig.6. The single phase inverter is arrange to operate in voltage boost or bypass mode and is having the ability of providing 100% boost to the incoming AC line voltage sags down to 50%. The inverter DC bus is capable to handle deeper voltage sags down to 0 V. The static bypass switch plays a vital role to the entire DYSC product, which remains on under normal power line conditions. This allows very efficient single stage power through put with no harmonic voltage content added.

When the grid voltage is differs from the desired waveforms, the static bypass is turned off and (IGBT) inverter gets operating. Thyristor commutation is facilities by the inject inverter voltage. The missing voltage becomes the reference voltage which is calculated on the input side. The inverter provides only he missing voltage and the circuit is arranged to add this missing voltage to the input voltage to supply the required compensation. The time required to detect the sag, commutate the thyristors and begin compensation is less than 1/8 cycle.

DYSC does not depend upon the stored energy to compensate the missing voltage it draws power from input line whenever the missing magnitude is 50% or less.

The smallest DYSC units exclude sufficient energy storage to compensate for 100% missing voltage for 3 cycles. Optional additional to range, in the form of can raise the ride although time to 15 cycles or more.

The latter feature will permit the mini DYSC to protect against the interruption of power up to the first utility reclose operation following fault. A pre valent type of PQ event in high lighting suburban areas.

B. Three phase pro DySC and mega DySC

The single phase DYSC is changed to improve the three phase protection function in pro DYSC product for lower power three phase four wire applications up to 500 KVA. A series transformer is connected devise provides more favourable solution for higher power levels up to 2MVA which is similar to other solutions in market such as GE'S, SSVR, SST's IVR,DVR.

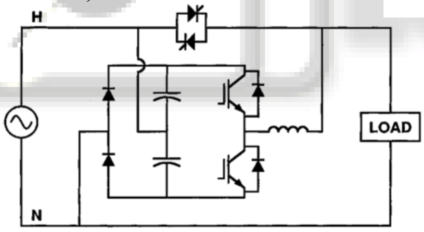

Fig. 6: Single Phase DySC Topology[12].

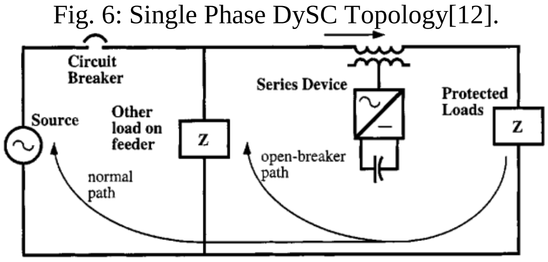

Fig. 7: Current path for series DVR-type device with open input breaker[12].

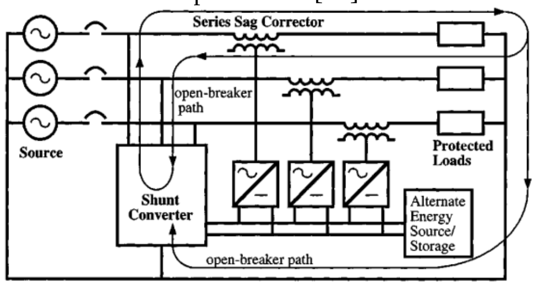

Fig. 8: The Mega DySC series-shunt circuit provides a load current circulation path[12].

These units performs by introducing a transformer in series with the line and inject a voltage (using an inverter) to compensate for voltage sags. Most systems are limited to improvement power quality problem down to 50%. The DYSC can manage deep voltage sag and can supply ride through it adequate energy storage is provided.

But the series connected DVR type of solution is limited. It is required low impedance current path on the utility side to permit the load current path to be completed as seen in Fig.7.

The higher power DYSC can perform either under a deep voltage sag situation or with an open upstream breaker. The unique ability is open upstream breaker. The unique ability is shown schematically in Fig.8.

C. Mega DYSC combinations

The multiply redundant sources such as UPS, generators, and multiple distribution feeds are only the solution for applications which requires ultra-reliable utility power. This is ridicule when one considers that the utility transmission grid has extremely high availability with only the occasional voltage sag to mar its near perfect record. The use of independent distribution feeds with static transfer switches has not been sufficient to solve the problems of sags and transfer interruption at distribution level as the availability is much lower because of the faults which cause a localized downstream outage to occur so that this solution has not been adopted due to its higher cost to the utility and poor performance. An innovative technique to combine static transfer switches with a DYSC has been proposed by W.E. Brumcikle to provide extremely reliable and available power as seen in Fig.9.

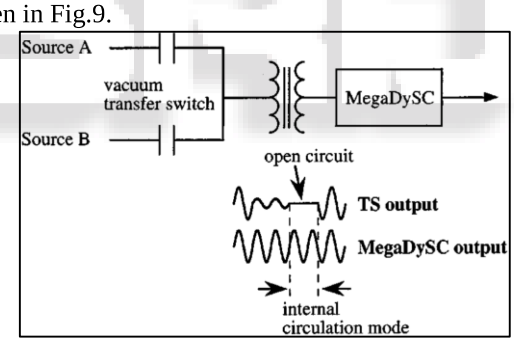

Fig. 9: Ultra reliable power is supplied cost effectively by using a vaccum transfer switch and a voltage sag corrector with ride through capability.

The recently introduced 27 KV vacuum transfer switches operate with an interruption time of 1.5 cycles [10] the mega DYSC with its internal load current circulation path is capable to maintain load voltage through the transfer interval. A series connected device such as DVR is unable to provide these functions. The voltage sags occurs on the transmission level, which would appears on both the independent feeders DYSC will also mitigate them.

The DySC is applicable as a utility interface for a longer energy storage devices or alternative energy sources having the advantage that the energy sources does not require fast transient response.

V. CONCLUSION

The DYSC have obtained grade response from 1998 as it has been in limited production. There is now vast response and a large installed base in critical process industries;

including semiconductors, automotive, optical fibres, plastics and computer numerical control machining. DYSC units have the advantages such as it is smaller in size and lower cost, while providing a high level of protection. It has been demonstrated that DYSC not only corrects the sags down to 50% but also provide protection from momentary loss of power. The operating efficiency of DYSC is greater than 99%. It has response time less than 1/8 th cycle as well as will have a long operative life at least 10 years.

In the DYSC the batteries are removed so that it also minimizes operation as and maintenance cost, and guaranties system availability.

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REFERENCES

[1] Y. H. Chen, C. Y. Lin, J.M. Chen, and P. T. Cheng, "An inrush mitigation technique of load transformers for the series voltage sag compensator," IEEE Trans. Power Electron., vol. 25, no. 8, pp. 2211–2221, Aug. 2010.

[2] M.F.McGranaghan, D.R. Muller,and M.J.Samotyj, "Voltage Sags in industial systems," IEEE Transaction Industrial Application, Vol.29, No.2, pp.397-403, Mar./Apr.1993.

[3] A. Bendre, D. Divan, W. Kranz, and W. Brumsickle, "Equipment failures caused by power quality disturbances," in Proc. IEEE IAS Conf. Record, 2004, pp. 482–489.

[4] Yong Lu, Guochun Xiao, Bo Lei, Xuanlv Wu, and Sihan Zhu, "A transformerless active voltage quality Regulator With the Parasitic Boost Circuit" ,IEEE transactions on power electronics, vol. 29, no. 4, april 2014.

[5] S. Subramanian and M. K. Mishra, "Interphase AC–AC topology for voltage sag supporter", IEEE Trans. Power Electron., vol. 25, no. 2, pp. 514– 518, Feb. 2010.

[6] Mahendra V Chilukuri, Lee Ming Yong, and Phan Yoke Yin, "Effects of voltage sag on single phase domestic and office loads," Electrical power quality and utilization Magazin, Vol.4, Issue 1, Sept.2009.

[7] A. Sannino, M. G. Miller, and M. H. J. Bollen, "Overview of voltage sag mitigation," in Proc. IEEE Power Eng. Soc. Winter Meet., 2000, vol. 4, pp. 2872–2878.

[8] J. Praveen, P. Bishnu, M. S. Venkateshwarlu, and H. V. Makthal, "Review of dynamic voltage restorer for power quality improvement," in Proc. 30th Annu. IEEE Ind. Electron. Soc., 2004, pp. 749–752.

[9] S.Khalid, Bharti Dwivedi, "Power quality issues, problems, standards and there effects in industry with corrective means", International journal of advance in engineering and technology, May2011.

[10] M. H. Bollen, Understanding power quality problems, voltage sags and interruptions. Piscataway, NJ, USA: IEEE Press, 2002.

[11] D. M. Divan, "Single phase ac power conversion apparatus," U.S. Patent 5099410, March 1992.

[12] W. E. Brumsickle, R. S. Schneider, G. A. Luckjiff, D. M. Divan, and M. F. McGranaghan, "Dynamic sag correctors: Cost-effective industrial power line conditioning," IEEE Trans. Ind. Appl., vol. 37, no. 1, pp. 212– 217, Jan./Feb. 2001.

[13] Nicolas Louzan Perez, Manuel Perez Donsion, "Technical methods for the prevension and correction of voltage sags and short interruption inside the industrial plant and in the distribution networks," International conference on renewable energy and power quality, 2003.