November, 2015

Transformers for Solar Energy Farms

Industrialized nations throughout the world have added solar power capacity into their grids to supplement and provide an alternative to conventional energy sources. Long distance transmission networks allows for remote locations of solar farms to displace fossil fuel consumption. The majority of solar power is generated via photovoltaic (PV) systems which utilize multiple ground mounted solar panels that convert sunlight directly into electric power.

According to reports from GTM Research and the Solar Energy Industries Association (SEIA) , in the first half of 2015, solar energy comprised 40 percent of all new electric generating capacity brought on-line in the U.S.

Large PV Solar Power Farm

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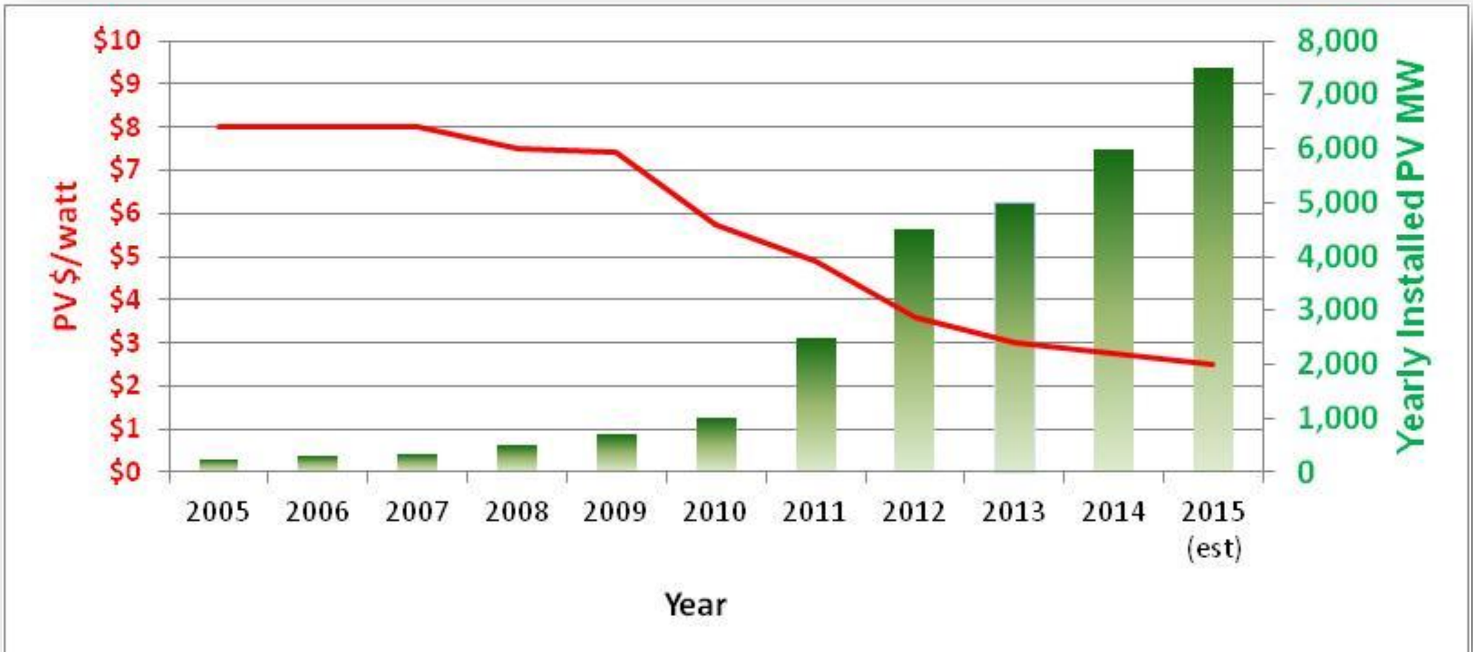
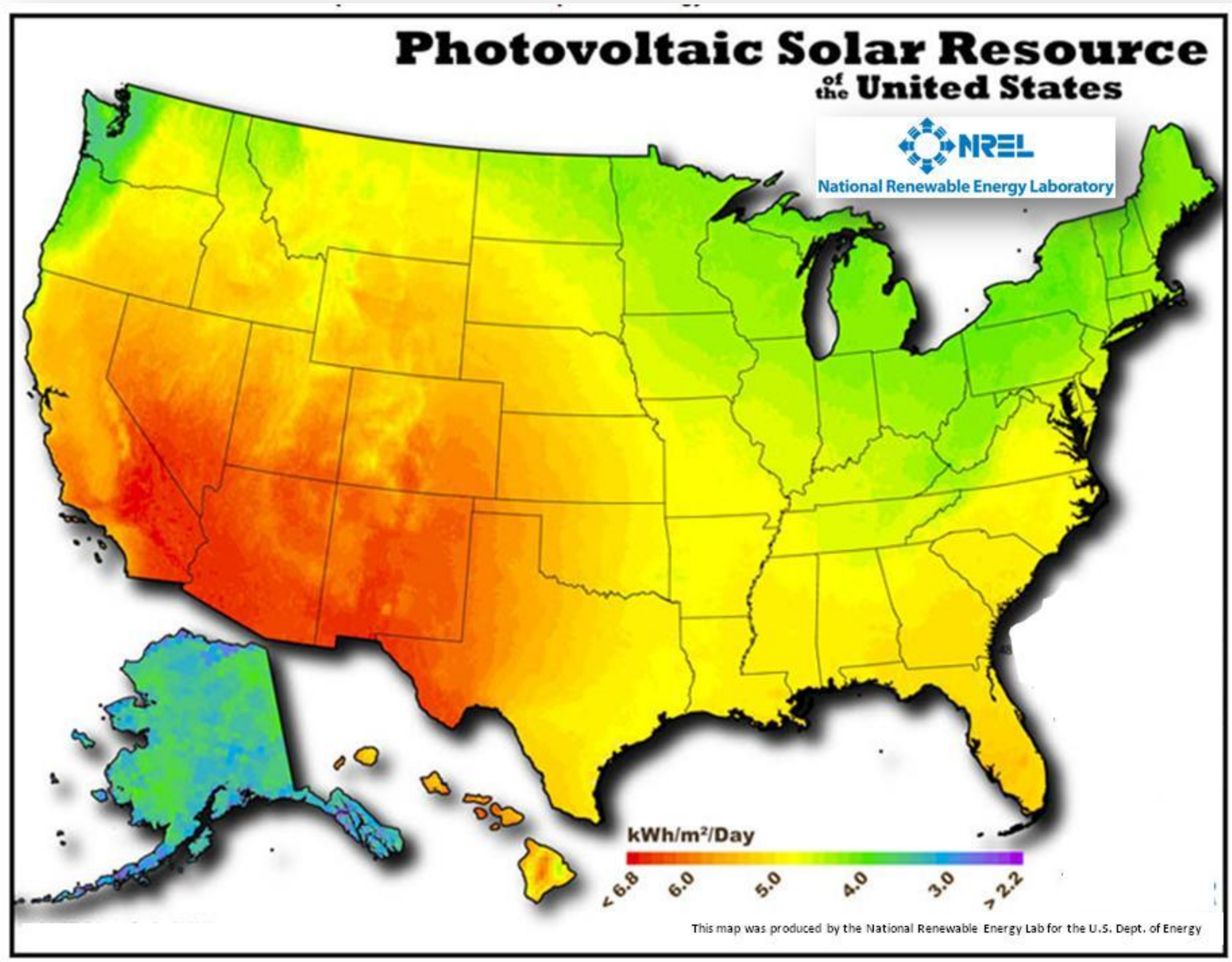
Solar energy generation has become very price-competitive with conventional energy sources as the price of photovoltaic panels has decreased dramatically and via technological advances in DC/AC inverters. Couple these savings with the solar investment tax credit (ITC) which was passed in 2006, prices for utility based solar energy have fallen by over 60 percent since 2010. As a result, nearly 26 GW of solar capacity have come online since 2010 which equates to 90 percent of all solar capacity installed in the U.S.



The illustration above graphs the annual U.S. production rate against the cost to produce. Production rates have actually increased by over 100 times within the the past 10 years! As is the case with wind power, the demand for solar power is well positioned to continue growing at a pace unprecidated to that of “conventional” energy alternatives (coal, gas, hydro).

The vast majority of U.S. installed solar farms to date are located in the desert southwest. The Solar Star is a 579 MW photovoltaic power station near Rosamond, California. Completed in June 2015, it is currently the world's largest capacity solar farm, with 1.7 million solar panels covering 3,200 aqcres.

Utility-scale solar plants were nowhere to be found on public lands just a few years ago, largely because they were too costly to build. The Solar Star farm is located on land administered by the Bureau of Land Management. Thirty other solar projects have been approved for public lands, and nine are currently under construction in California and Nevada.



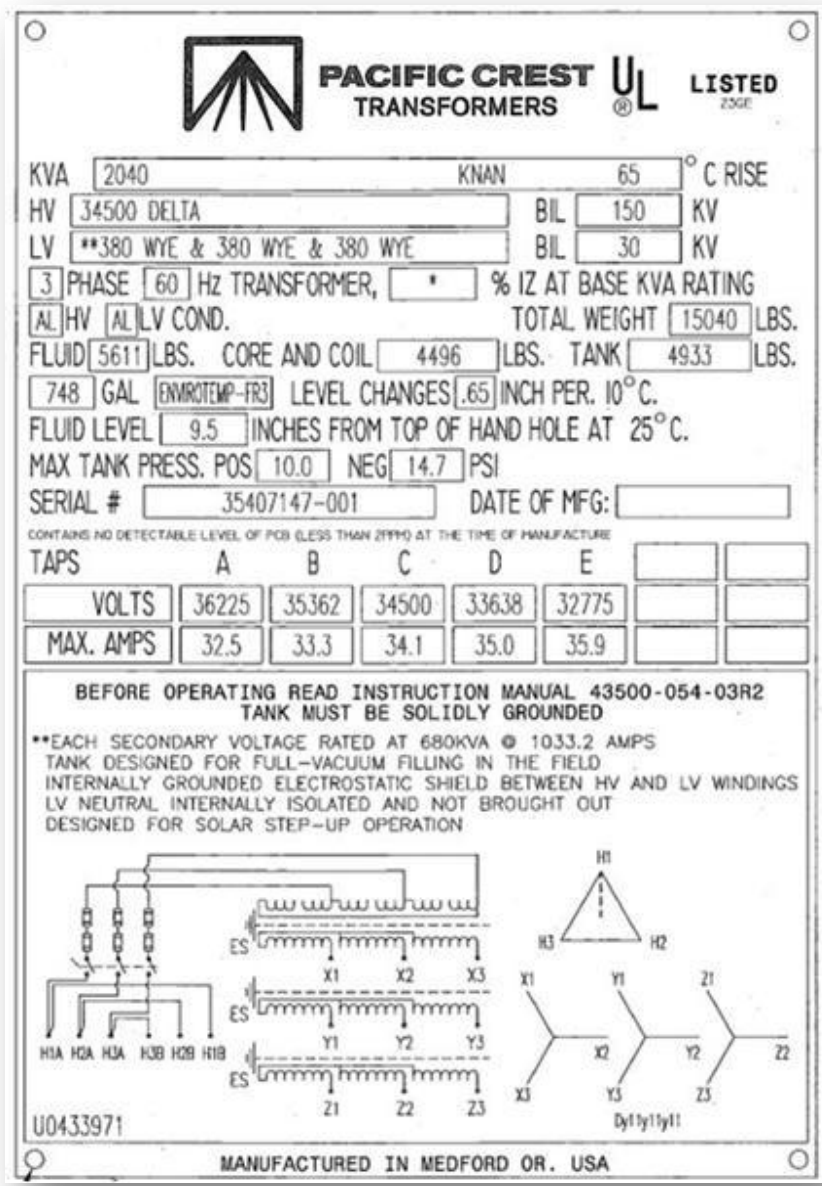
The federal government manages almost 250 million acres of U.S. territory, most of it in the West and much of it desert, perfect for the production of solar power. The map above, provided by the National Renewable Energy Laboratory, provides a visual of the significant advantage that the southwest territory provides.

The key components found in a PV solar farm are comprised of a solar array which produces a DC voltage output. Large photovoltaic solar power facilities have literally millions of PV cells. They are connected in series/ parallel to form solar panels. The panels are interconnected so as to produce a DC voltage and current output matching that of the capacity of the inverters to which they are connected. The inverter converts the DC input to a low voltage AC output. The output is connected to a step-up transformer which transformers the inverter output to a distribution voltage level (15 to 35 kV class) which in turn is fed to a substation class transformer. The voltage is then stepped up to a transmission voltage level (69 to 500 kV) which is connected to the HV grid.

These are the primary components in a PV solar farm, but there are a host of other components including disconnect switches, switchboards, power factor correction devices, and solar panel mounted solar tracking motors.

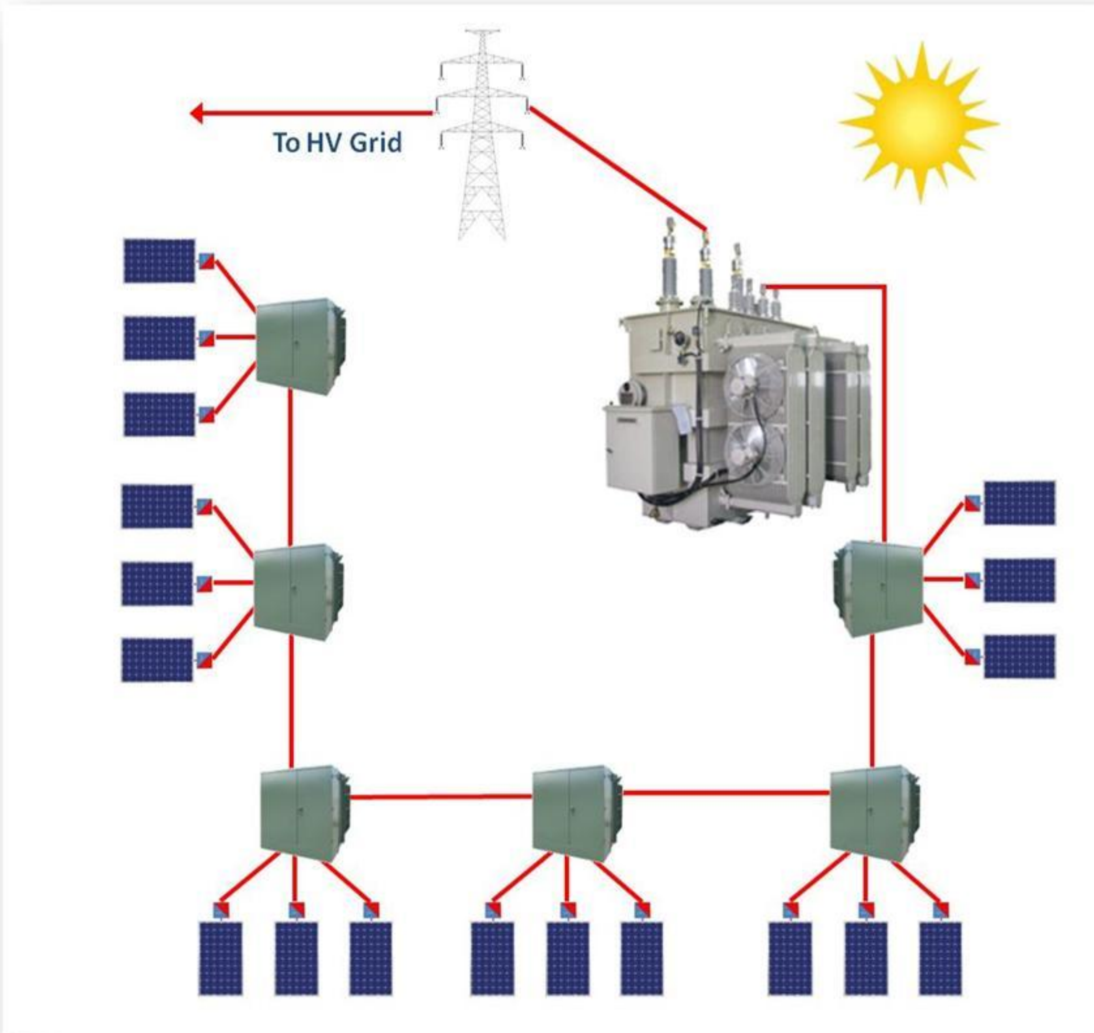
Although many advances have been made in the design of the inverters, their maximum output remains relatively low, typically about 5 KW, thereby necessitating the use of hundreds of inverters on large solar power farms.

Since the impedance of an inverter is very low, a small change in phase difference between the inverter and the grid voltage could result in a large imbalance in active power flow. For parallel operation of the inverters, the output voltage of each must be kept strictly in phase in order to insure equality of the output active power. The circulation of reactive power between the inverters can lead to their being overloaded. In order to suppress these circulation currents and to prevent DC-link over voltages, it is necessary to provide a galvanic isolation between the inverters. Galvanic Isolation means that the circuit is separated from the signal source in such a way that DC current cannot bridge the connection. In other words, there is no direct connection. The connection is only via electro-magnetic induction. This translates to a separate transformer winding for each inverter connection. This of course can be accomplished by providing one transformer for each inverter, OR in order to help reduce costs, one can use one transformer with multiple independent low voltage windings.



The nameplate to the right provides an example of such an approach. The transformer has a total kVA rating of 2040, BUT is made up of a common primary and 3 separate and independent wye connected secondary wind-dings with each having a rating of 680 kVA.

Such an approach significantly reduces the total cost of step-up transformers required for a solar farm while also reducing space requirements and installation costs. When provided as a padmount transformer, solar panel cable runs and loop feed transformer connections can be easily be accomplished via underground cable runs.



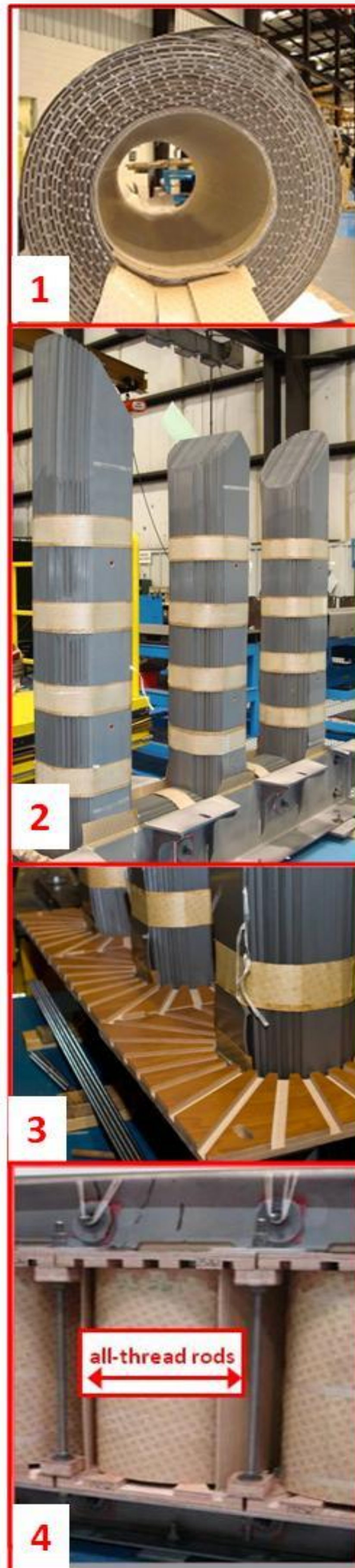
The above provides a visual as to how a solar farm utilizing multiple secondary input step-up transformers would connect the key components to the high voltage grid. Transformers with this configuration are anything but "off the shelf". Their construction must be highly reliable, highly efficient, and must cool effectively. As technology progresses, the total kVA rating requirements are sure to rise.

Pacific Crest Transformers solar power step-up (SPSU) is ideal for connecting solar farms to the electricity grid at large-scale solar power installations. Reliable and efficient, PCT's step-up transformer is an engineered solution with the design flexibility needed for the solar market. PCT's West Coast U.S. location also provides for quick delivery.

The SPSU is uniquely designed for the additional loading associated with non sinusoidal harmonic frequencies often found in inverter-driven transformers. An innovative system of multiple windings reduces transformer costs and minimizes transformer footprint by combining the step-up function to fewer transformers than other systems.

Designed and constructed to meet and exceed earthquake standards, the SPSU is rated for installation in the highest earthquake rating zones. In addition, PCT's SPSU PV solar converter step-up transformer incorporates a variety of fluids, including less flammable fluids required for enclosed applications.

The SPSU model features circular windings(1) that spread the radial forces evenly over their circumference and have cooling ducts throughout the coils, eliminating hot spots that lead to pre-mature insulation breakdown and ultimately to transformer failure. The coils are positioned over the legs of the cruciform stacked core(2). Upper and lower pressure plates(3) routered to provide uninhibited flow of the insulating fluid insure against overheating of the conductor and winding insulation. Heavy duty upper and lower core clamps(4) are secured together via steel all-thread rods which apply tension to the pressure plates to contain axial forces exerted during a fault condition.



These forces must be contained to prevent telescoping of the coils which can result in short-circuited winding turns and coil failures.

The pictures to the right show the initial assembly of a SPSU trans-former. There are three separate transformers sharing a common core. The three trans-formers are stacked one above the other with each including its own set of upper and lower pressure plates. In the upper photo, the final pres-sure plate is shown being put in place. Note the oil flow ducts routered into the bottom of the plate.

The lower core clamp can be seen on the bottom of the lower picture. Insulated through-bolts are used to compress the core laminations. Once the upper horizontal core is in place, a similar core clamp will be installed. With both clamps installed, steel all-thread bolts are added which run from the upper core clamp through the lower clamp. Hardware is added and torqued to spec thereby securing all pressure plates in place to lock winding turns in place.

Preliminary testing can now be performed to insure that each winding ratios correctly including all tap connections.

The low voltage buss-work is then added.
The winding starts and finishes for each of the three transformers are wye connected complete with welded termination pads which will be bolted to the low voltage tank bushings.

Next the high voltage windings are insulated and terminated. Although the three sets of low voltage windings are independent from one another, the high voltage windings are paralleled thereby tripling the cross sectional area of the high voltage conductor necessary since the high voltage total kVA is to be equal to three times that of the individual l low voltages.

Once the core/coil assembly is completed, it is lowered into the transformer tank. The high voltage terminations are connected to the loop feed HV bushings. Each of the three low voltage transformer windings is connected to the appropriate tank bushings.

The lower picture to the right shows a “tanked” transformer ready for testing. Note that with the exception of the additional low voltage bushing it appears to be a standard padmount transformer.

After all testing is complete, the tank top is welded in place, the padmount compartments are installed, and the final paint is applied.

Once inspected by Quality Control, the transformer is ready for shipment.

Truckload of Solar Power Step Up-Transformers Leave The Factory

Pacific Crest Transformers innovative SPSU product offering provides a means in which to minimize the number of installed transformers required for large solar power farms.

The Solar Power market is growing dramatically and is poised to become the dominant source of new power generation. PCT is well positioned to provide the optimum solution for today's as well as tomorrow's demands for efficient, reliable, load specific transformers.

Pacific Crest Transformers: Providing innovative solutions for today's complex challenges